Final Report

LSS Systems
Planning and Performance Program

Contract NAS8-36670

Prepared for:

National Aeronautics and Space Administration
George C. Marshall Space Flight Center
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Control Dynamics

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LSS Systems Planning and Performance Program
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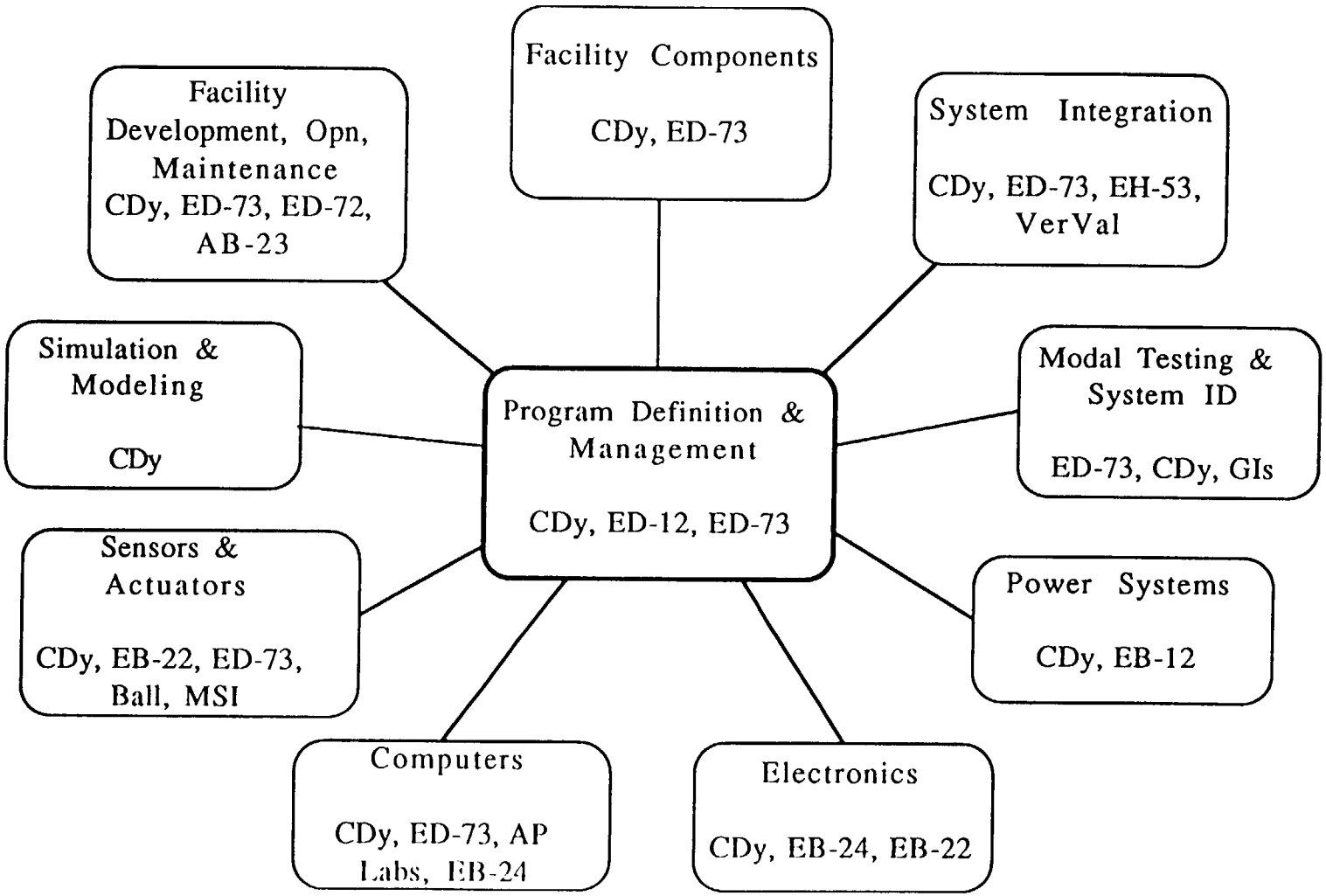
1.0 Introduction

The LSS Systems Planning and Performance Program involved the development, integration and operation of the Control-Structures Interaction/Controls, Astrophysics, and Structures Experiment in Space (CSI/CASES) Advanced Development Facility; enhancement and operation of the Active Control of Systems (ACES) Ground Test Facility and participation in the CSI Guest Investigator Program. Accomplishments included the overall systems engineering responsibility associated with laboratory development, including specification, fabrication, testing, integration, and operation of the laboratory systems consisting of the test articles, sensors, actuators, RTCS, data acquisition systems, optics, power and electronics, Logicon Control Dynamics supported the day to day maintenance and operation of the facility, including both control and dynamic testing as well as simulation, structural modeling, control methodology design and implementation, and facility computer software.

This report addresses the ACES facility, CSI/CASES facility and the Guest Investigator program on the ACES facility. The accomplishments made in several areas for each facility are discussed, the current status of each facility is detailed, and recommendations for future work are prescribed.

Included in this report is Appendix A that lists all documents, drawings, blueprints, manuals, schematics, reports, papers, publications and other information that have been provided over the course of the contract. These items are located in the LSS Control Room in Building 4619.

LSS Program Team



General Activities

- **Contract Management**

  Bi-Weekly/Monthly Meetings & Minutes
  Monthly Status Reviews to NASA and CDy; Bi-weekly Financial Status Updates (CDy)

- **Demonstrations**

- **Materials**

- **Facility Integration & Verification (CSI/CASES)**

- **Facility Operation & Maintenance (ACES & CSI/CASES)**

- **Computer System Administration (CSI/CASES)**

- **Training Session for NASA**

General Activities

- **Documentation**

Prepare facility overview doc'n for control room (4 drawers +)

Prepare & Deliver final reports:

ACES: ACES System Overview doc't, ACES Software Description doc't,
ACES operator's manual
ACES Finite Element report

CASES: Operator's Manual,
Finite Element report, Simulation doc't,
SMS report, Auto-Cutoff/Sync Gen report,
Mux/Demux manual, PC Board Interface report,
Signal Processing doc't,
Test log notebook,
Test plot notebooks (DS, AMED, BLT, System, etc...)

Preparing final reports:
CASES System Doc'n, CASES System Testing Report
RTCC manual, AMED & Debug reports

2.0 ACES Facility

This section discusses the activities involving the ACES facility. This includes Guest Investigator Testing, structure maintenance, and documentation. Also listed are recommendations for facility upgrades.

SSC Activities

- **Testing**

  Ohio University – further investigation of pendulum mode: identification and control.

  9/92: On-site open and closed loop testing, unsuccessful at dampening pendulum mode.

  1/93: OU provided custom noise disturbances for AGS.
  LCD performed open loop tests and shipped resulting data to OU.

- **Facility**

  Instrumentation amplifier that serves Y-axis BET LVDT repaired by Data Tape.

  HP 9000 computer replaced by NASA (Kissel) due to failure in I/O function.

  Sine sweep code in control program corrected to produce proper sweep function.

  Elliptic filter boards installed in COSMEC (GI testing had previously prohibited).

SSC Activities

- **Documentation**

SSC Facility Operator's Manual	11/92
SSC Facility Software Description	12/92
SSC Transfer Functions Packet	2/93
SSC Laboratory Overview	3/93

ACES Facility: Future Recommendations

Recommended Upgrades	Benefits
Update HP 9000/COSMEC/AP with MMVC computer	Increased sampling rate, controller order, expandability
Utilize present ACES computer for an SMS	Expand safety monitoring capability
Increase speed & accuracy of LaMOD	Increased control performance and evaluation
Investigate intermittent COSMEC I/O failure	Eliminate COSMEC problems
ACES-IV: Add tip roll motor	Increased control authority at tip
Improve simulation model of BET	Add 8 Hz mode to simulation

ACES Active Control Evaluation of Spacecraft
AP Array Processor
BET Base Excitation Table
LaMOD Laser Motion Optical Detector
MMVC Multibody Modeling, Verification and Control

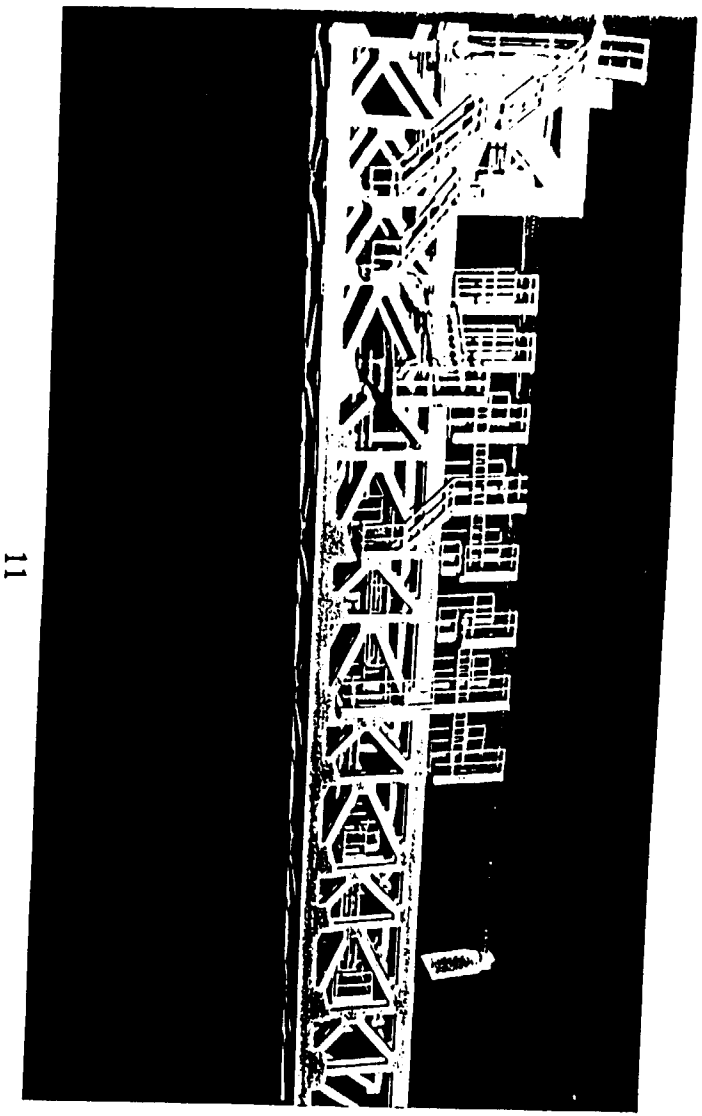
3.0 CSI/CASES Facility

An extensive amount of work has been performed relating to the CSI/CASES facility. The structure has been assembled, complete with sensors and actuators and a disturbance system. The computer system, and its corresponding software, has been developed and integrated with the hardware. A simulation tool and finite element model have been developed and tested. Documents have been written which discuss each component, as well as overview documents and users manuals. The next several sections break out in more detail the work performed relating to the CSI/CASES facility.

3.1 Facility Overview

This section describes the actual CSI/CASES facility and its objectives. There are breakdowns of sensor and actuator locations as well as pictures of the hardware. Also provided are recommendations for future hardware upgrades.

CSI/CASES GTF (Ground Test Facility)



- **Objectives:**

  Investigate CSI (Control-Structures Interaction)

  Conduct CSI Guest Investigator studies

  Investigate deployment dynamics

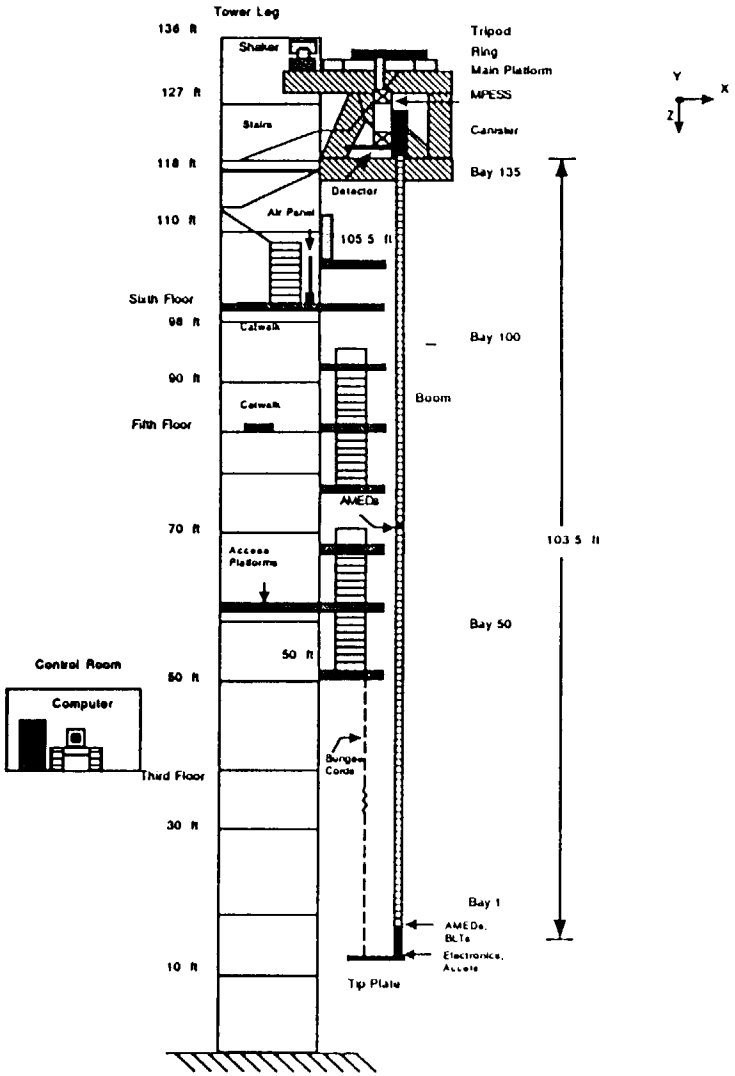
  Support ground testing of potential Flight Exp't

- Facility: NASA/MSFC Bldg. 4619
  Main Platform at 132 ft.

- Test Article: Vertically Suspended
  105 ft deployable boom (15 " D)
  Simulated MPESS
  Simulated Occulter Plate (6'x6')

CASES Controls, Astrophysics, and Structures Experiment in Space
IE Flight Experiment GI Guest Investigator
MPESS Mission Peculiar Experiment Support Structure

CASES GTF (Ground Test Facility)



Sensors:

2 gyros at mid-point, 2 at tip
3 accels at tip, 3 at MPESS
4 disp sensors at tip plate

Boom Motion Tracker
DS sensors (force, accel, pos'n, air gap, press, flow)

Actuators:

2 reaction wheels at mid-point, 3 at tip
2 thrusters at tip

2 DS shakers

Computer: 64 I, 64 O, 100 order ctlr at 250 Hz

Sun Host plus Real-Time CPU
with 3 Array Processors

CASES Controls, Astrophysics, and Structures Experiment in Space
DS Disturbance System
MPESS Mission Peculiar Experiment Support Structure

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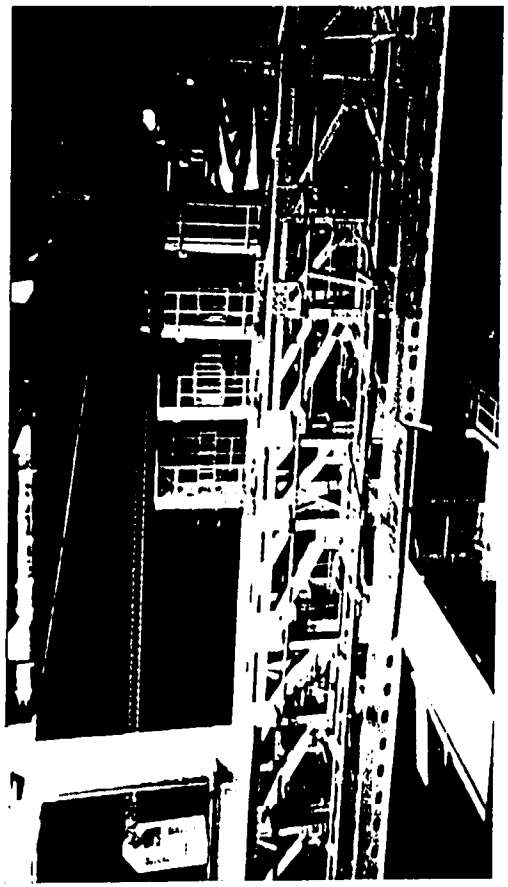
Control Dynamics

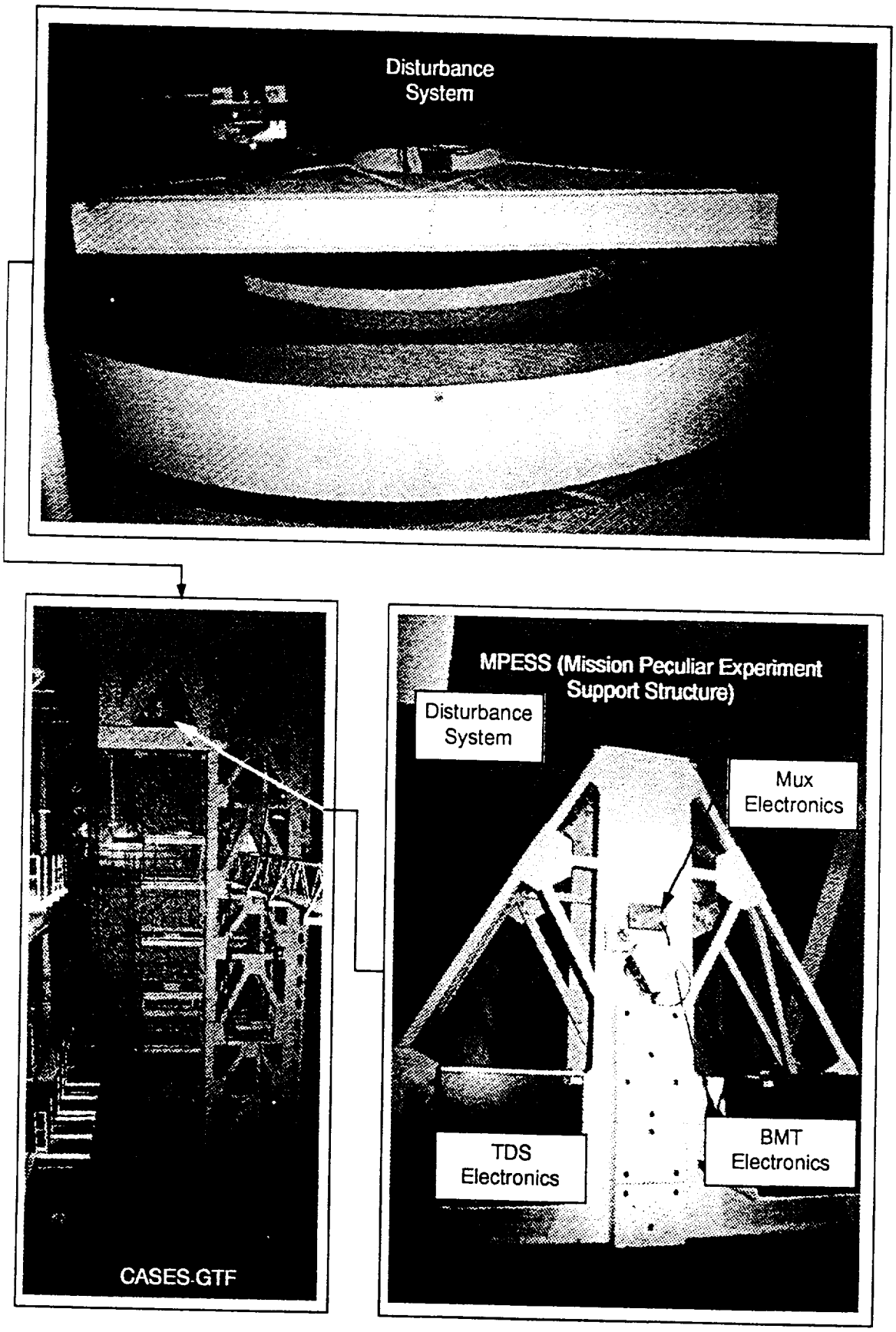
Facility Progress



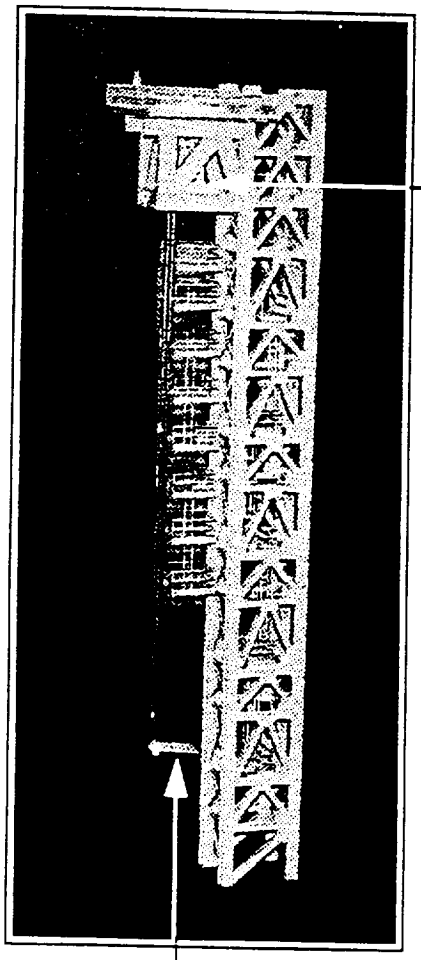
- Finish curtain enclosure system
- Add MPESS access platform (unmotorized)
  Deliver motor & starter
- Add facility lighting system, garage door windows & doors, AC unit
- Finalize MPESS (- CW's, + Simulated Detector)

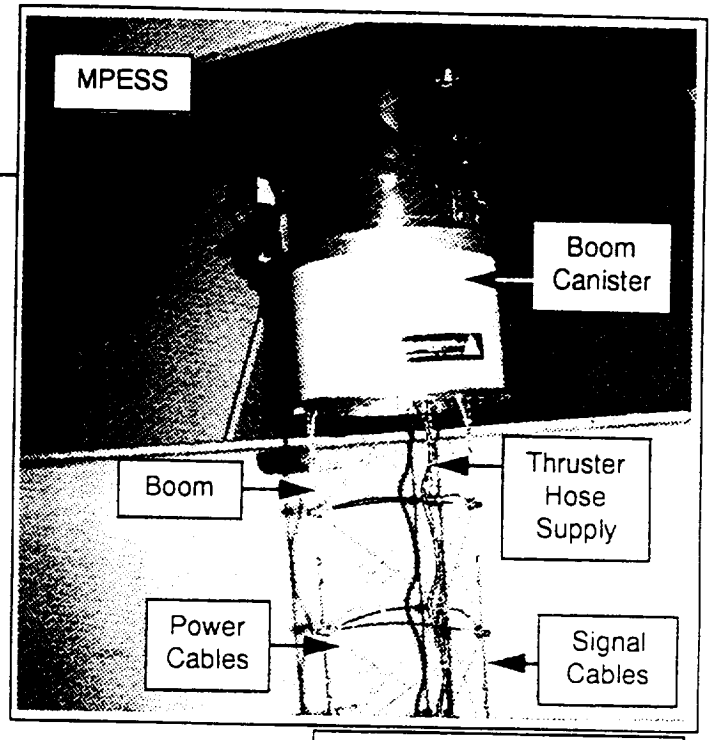
AC Air Conditioner
CW Counterweight
DS Disturbance System
MPESS Mission Peculiar Experiment Support Structure

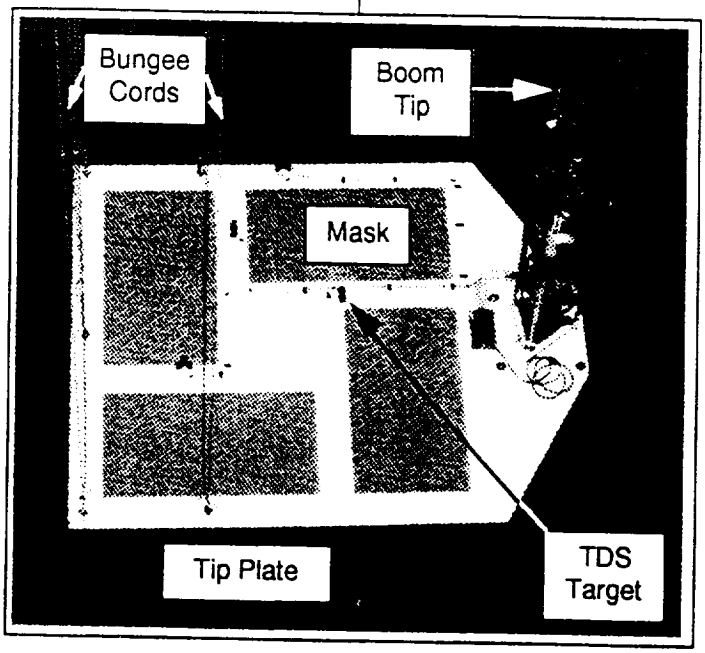
CASES GTF Main Platform

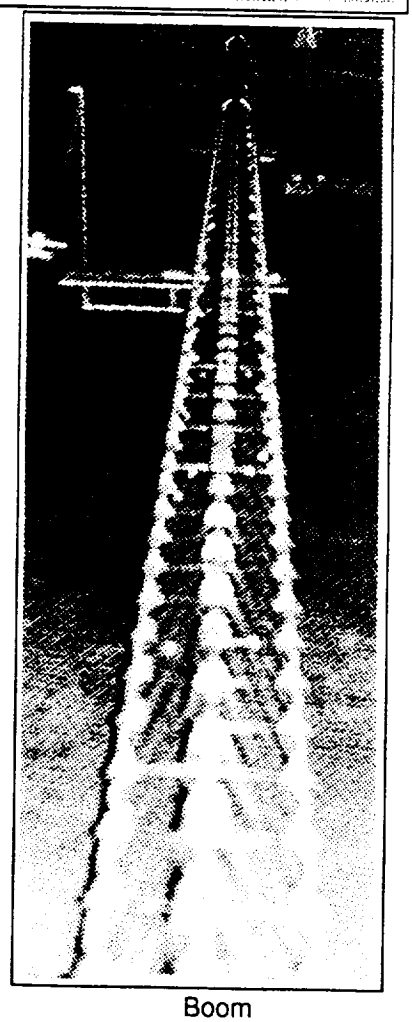


CSI ADF Test Articles









Boom
(Horizontal Deployment)

Facility: Future Recommendations

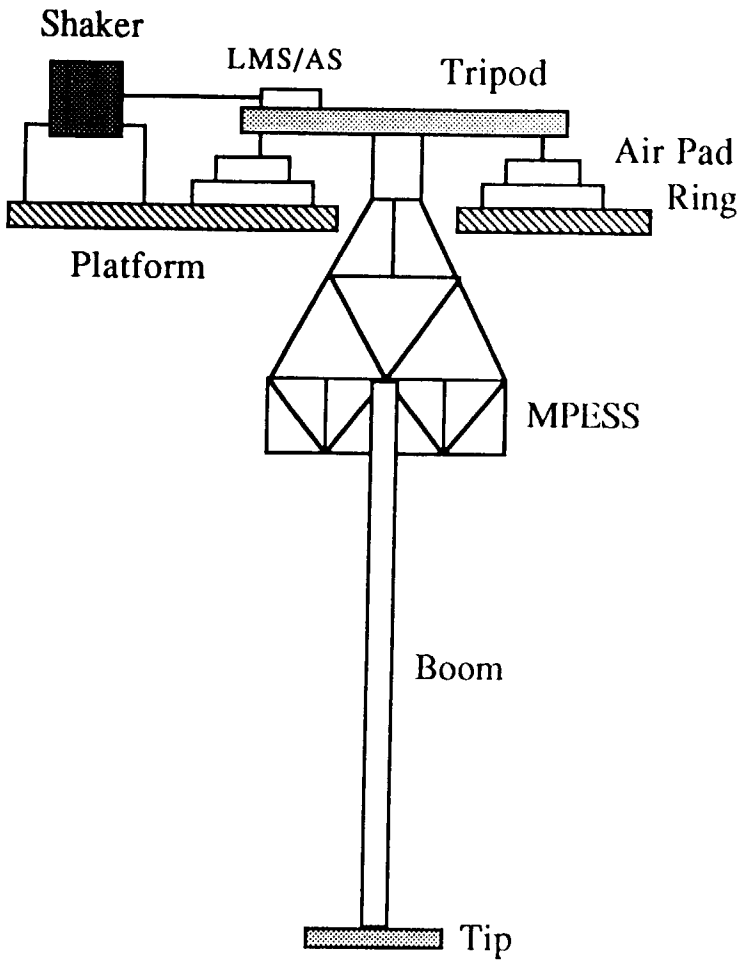
Recommended Upgrades	Benefits
Add raised platform (& stairs) on floor near tip for visitor's viewing	Easy access to tip components by facility workers Convenient viewing of tip components by visitors
Add motor/starter to MPESS access platform	Motorized platform
Extend AMED access platform	Easy access to mid-boom instrumentation
Replace rails on access platforms	Increased safety
Add small hoist system for access platforms	Small loads (tools & test equipment) won't have to be hand carried up ladders
Improve tip suspension system	Less dynamic interaction than bungees

AMED Angular Momentum Exchange Device
MPESS Mission Peculiar Experiment Support Structure

3.2 Disturbance System

This section discusses the work performed on the CSI/CASES disturbance system, along with a description of the disturbance system.

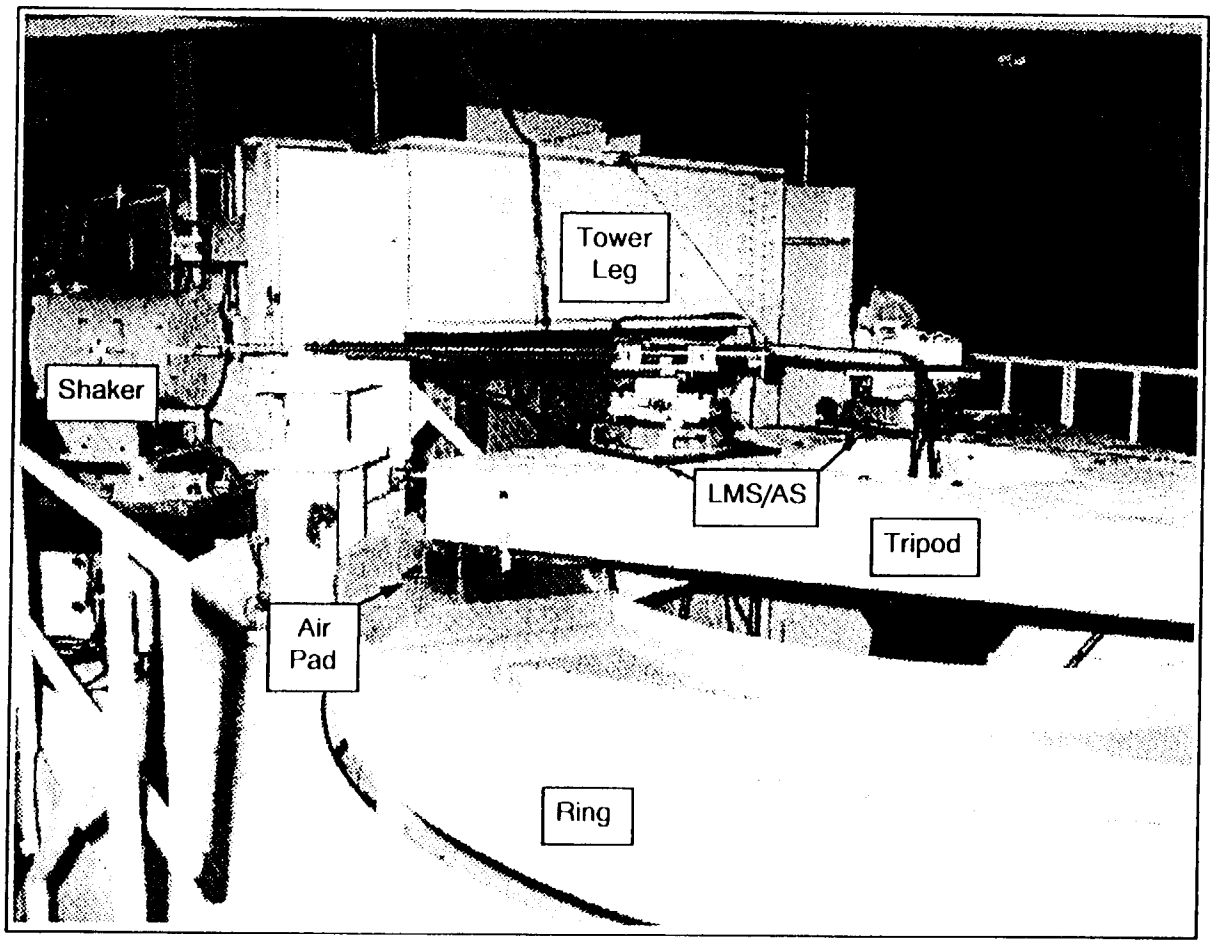
Disturbance System



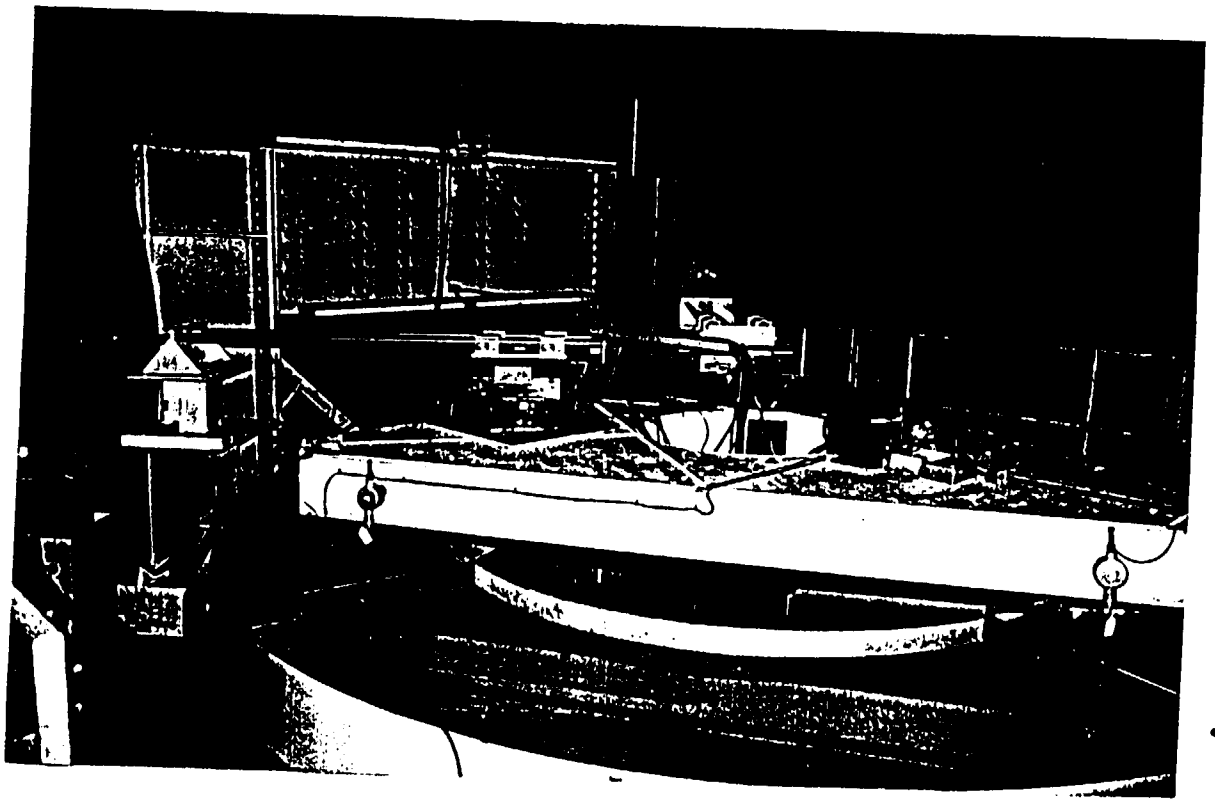
- Applies 2DOF disturbances to base of exp't Located at top of platform
- Components: Ring Bearing, Leveling Mechanism, Tripod, Air Pads, EM Shakers, Linear Motion System, Alignment System
- Air Pads provide "frictionless" surface
  Air Pad "spring constant" set above freq range of interest
- Tripod is attached to simulated MPESS, which supports experiment

AS Alignment System
LMS Linear Motion System
MPESS Mission Peculiar Experiment Support Structure

Disturbance System



Disturbance System Progress



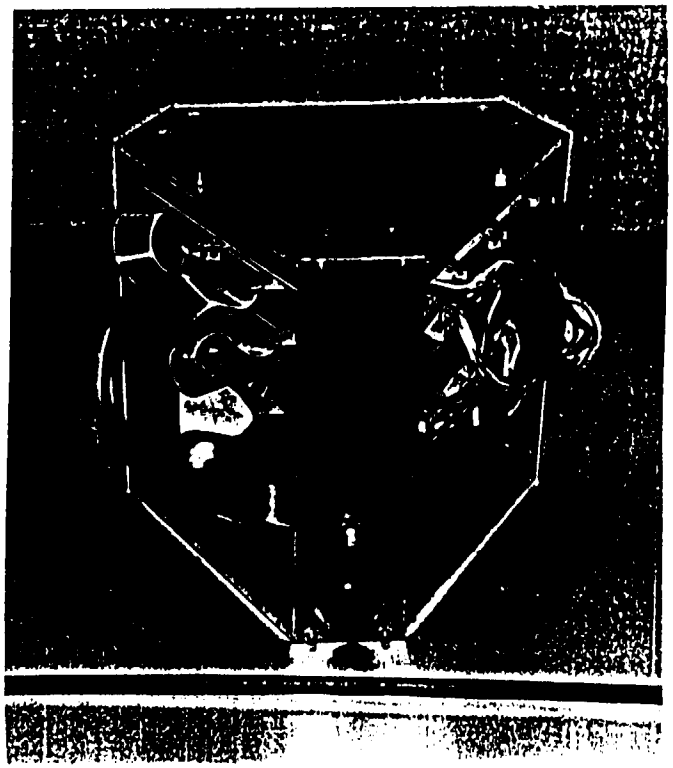
- Interface DS command from RTCC to shaker electronics; Add shaker current meas't to Mux
- Add signal conditioners for force transducers; Add gain to accelerometers
- Add shaker enable/disable relay (MSI, CDy); Interface with Auto-Cutoff system
- Repair/Replace force transducer joints
- Preliminary functionality testing & characterization testing

DS Disturbance System
RTCC Real-Time Control Computer

3.3 Signal Processing & Electronics

The first topic discussed in this section is the Mux/Demux system for the CSI/CASES facility, its development, and current status. The second topic is the debug system developed for the facility. This system is extremely useful for locating the source of problems involved with the electronics. The third topic is the power system for the facility. Many components of this system are located on the MPESS. Its components are described and progress listed. The final topic in this section is facility signal processing. Flow charts are provided to show signal flow paths for the sensors and actuators. Tests were performed on the system and the results are provided along with recommendations for future work.

Multiplexer System



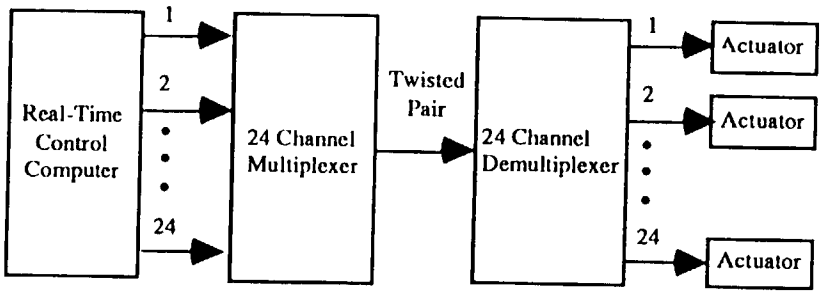
- Designed by CDy & EB-22, Implemented by CDy
- Samples 24 channels at rates to 950 Hz
- Differential amplifier (of sensors) reduces common-mode noise
- Gains from 1 to 1000 are easily changeable (resistor modification)
- 2nd order Butterworth anti-aliasing filters with 4 selectable cutoff frequencies
- Fault indicator circuit on Mux/Demux
- Mux I/V & Demux V/I converters are used to transmit signals
- Remotely selectable:
  sync frequency, filter cutoff frequency

I/V Current to Voltage V/I Voltage to Current

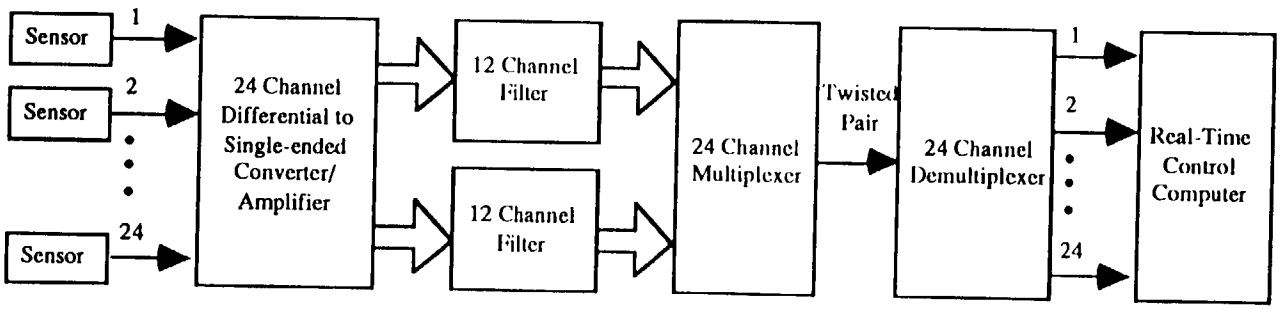
Multiplexer System

- Mux/Demux used for sensors and actuators

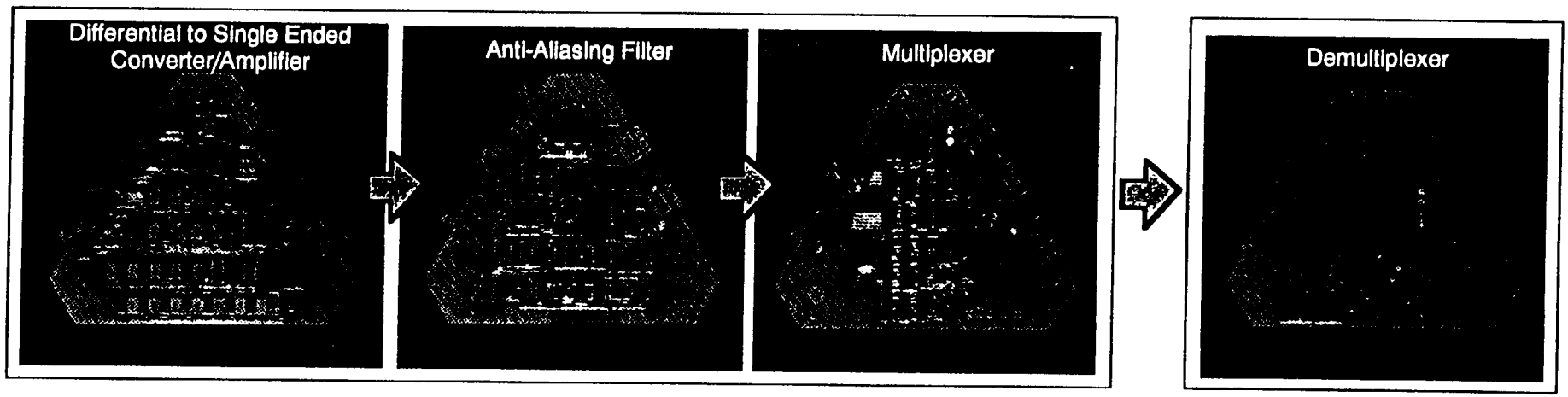
Actuator Mux/Demux:



Sensor Mux/Demux:



Cases Electronic Multiplexer System

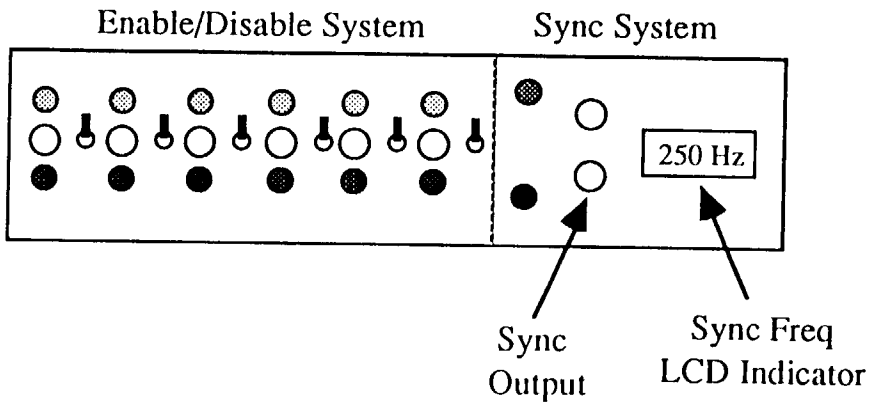


Mounted on Experiment

Mounted in Control Room

Mux/Demux: Sync Generator

- Designed & Implemented by ED-73 & CDy
- Generates the synchronization signals for M/D
- Sync frequency is selectable (100, 250, 500, 950 Hz) from CR
- RTCC Sync detector allows RTCC to generate sync during runs
- Resides in CR on Auto-Cutoff/Sync panel

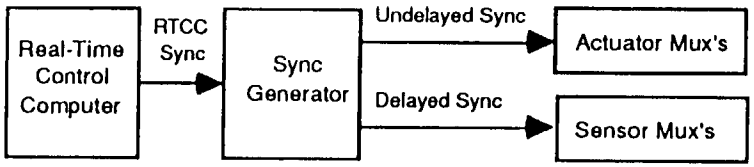


CR Control Room
RTCC Real-Time Control Computer

Mux/Demux: Sync Generator

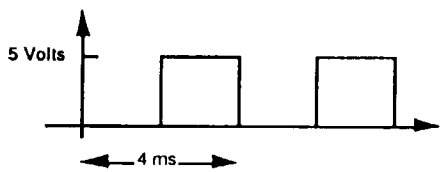
- Generates syncs for Actuator Mux's & Sensor Mux's

  Minimizes time delays in system: Delayed & Undelayed Sync's

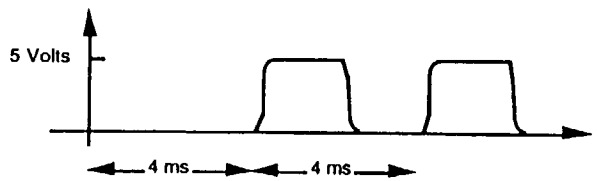


- Sensor Mux sync is filtered to prevent cross-talk between other M/D signals (di/dt is limited)

Actuator Sync Signal



Sensor Sync Signal

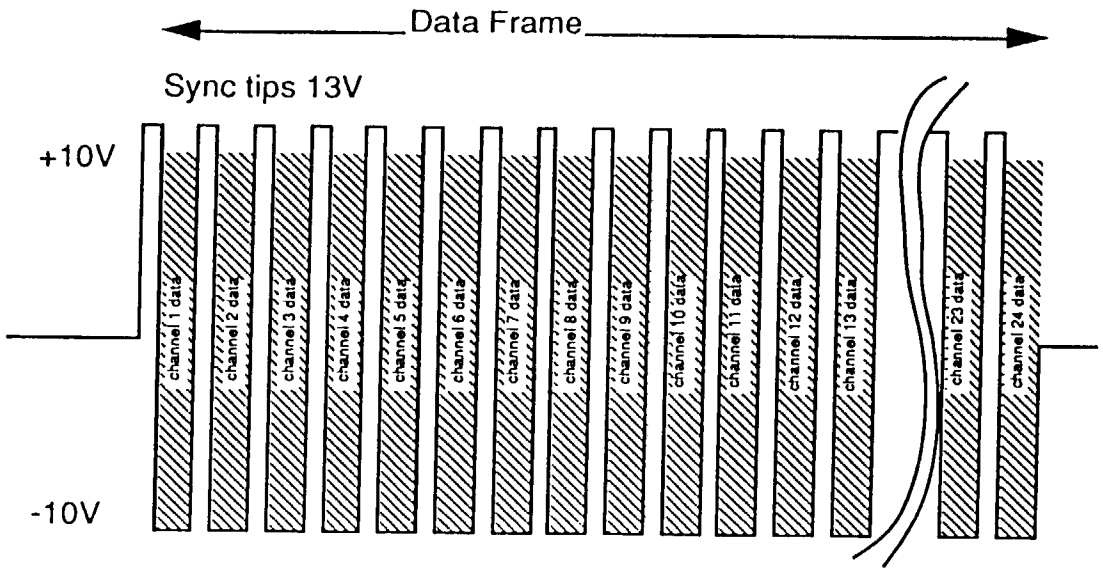


- M/D will not work without correct sync signal: Always verify Sync

  Common Sync: All M/D's will not work if one M/D fails

Mux/Demux: Troubleshooting Signal

- Demux Comb signal is available for troubleshooting: very useful signal
- Demux Comb is the Mux'd signal in the CR prior to Demux'ing
- Provides observation of all 24 sensor signals on one signal



Sync Duration	16 micro-sec
Data Duration	24 micro-sec
Total Data Frame	960 micro-sec

CR Control Room

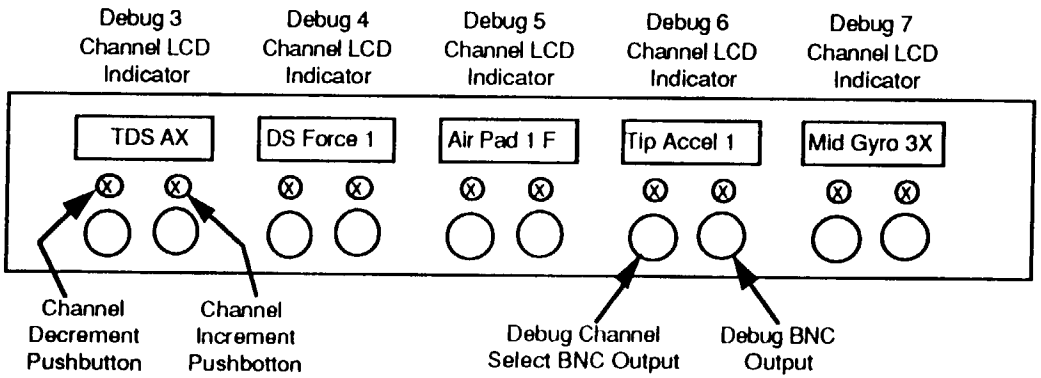
Debug System

- Designed & Implemented by CDy
- Provides access to boom signals (S & A's) from the CR
- Allows continuous (unmultiplexed) monitoring of selected signal
- Extremely useful

  locating source of problem (power, Mux, cable, sensor, actuator, etc...)

  comparing processed signals (Mux'ed & filtered) with raw signals

- Can also be used to provide remote signal injection into a Mux for in-place calibration



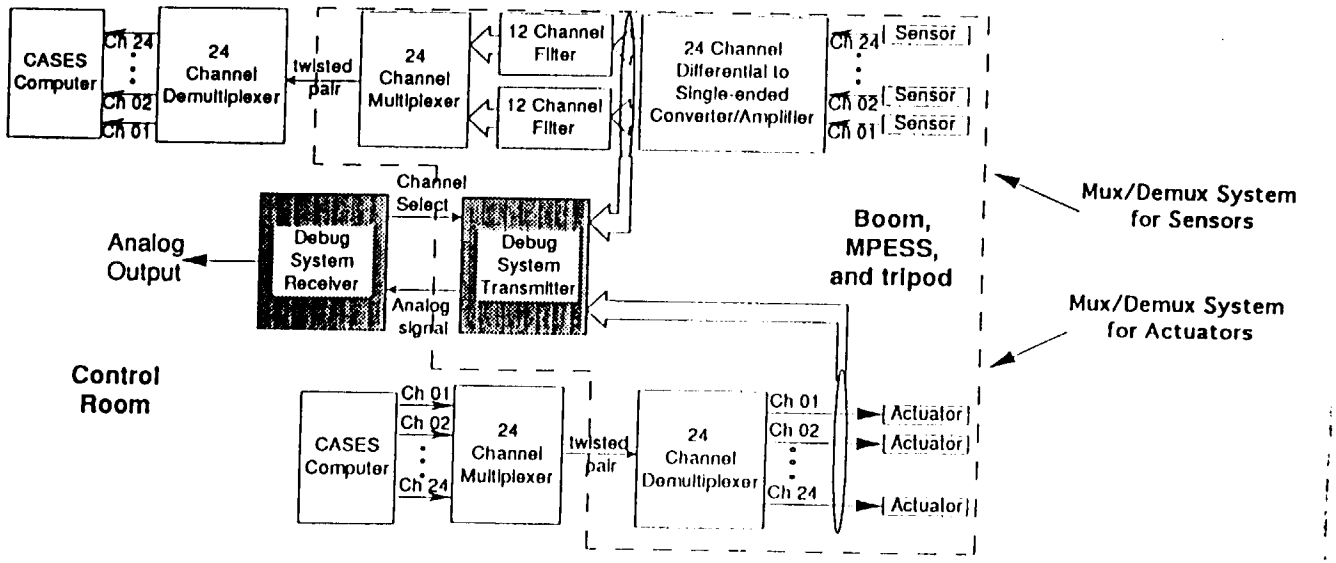
CR Control Room
S & A Sensor & Actuator

Debug System

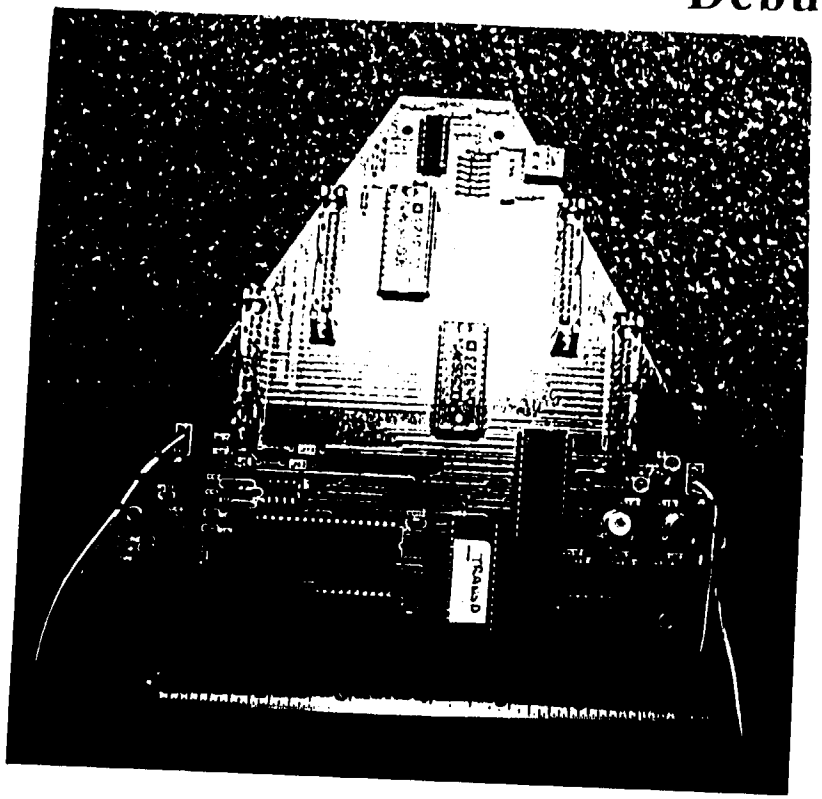
- Microprocessor based system with LCD displays in CR
- Two component systems: Transmitter & Receiver

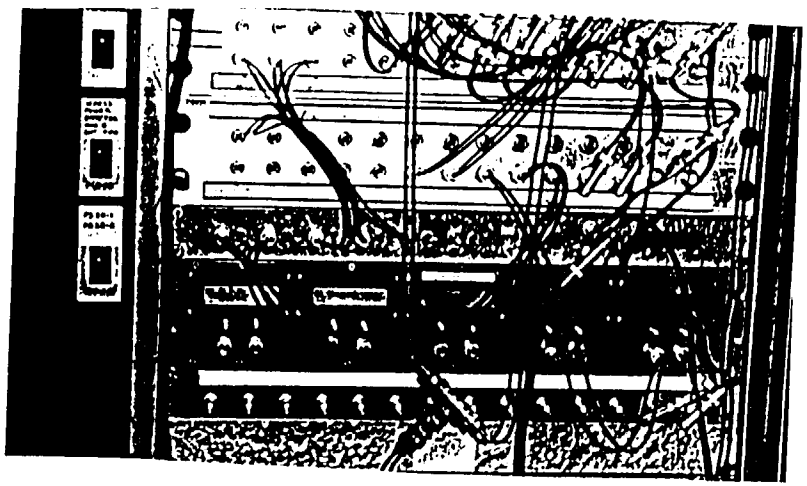
  Debug transmitter located at each M/D location (2 Boom, 2 Tripod, MPESS)
  Debug receivers (5) in CR

- Each Debug system provides access to 1 of 48 signals



Debug System Progress



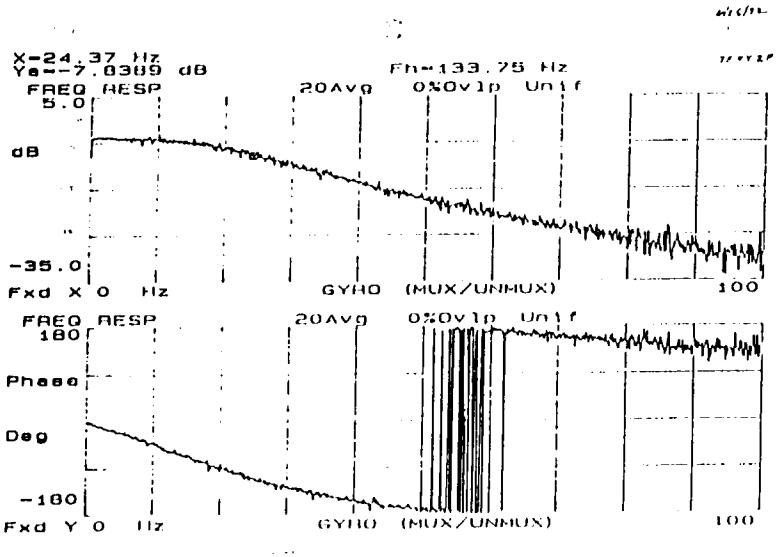


- Develop software for prototype debug system
- Design & Fabricate debug panel & mounting sys
- Populate & Test 5 debug transmitter PC boards
- Layout & Fabricate debug receiver PC boards
- Populate & Test 5 debug receiver boards
- Integrate rcvrs, Xmitters, rack, power, cables, etc.
- Test & calibrate debug system
- System presently operational

Debug System: Application

- Problem: Gyro natural frequencies were aliasing thru the 125 Hz filter
- Solution: Modify 125 Hz to 25 Hz filter for added attenuation for all gyro channels
- Debug Test: Observe gyro signal during BLT sweep

  Compare unmux'd, unfiltered gyro O/P via Debug with Mux'd, filtered gyro O/P



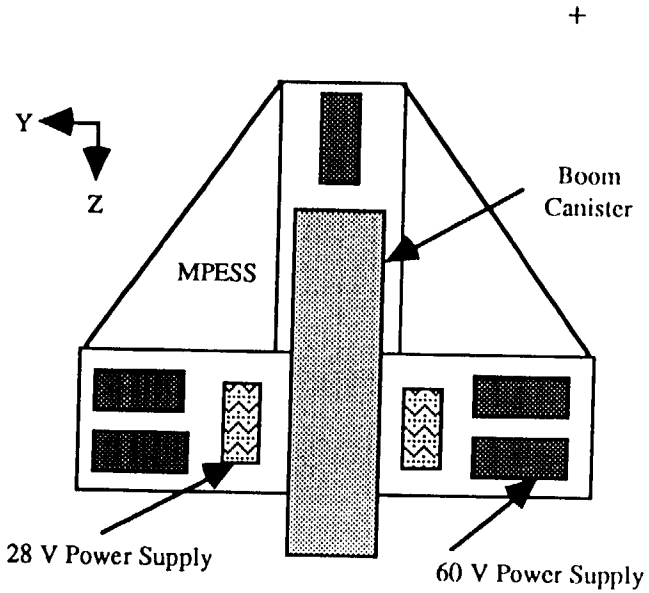
Transfer Function:
Mux'd gyro/Unmux'd gyro

TF shows effect of 25 Hz filter

Gain of TF = -3 dB from DC at 24 Hz

Note: Debug gain = 2 at time of test
(Prior to installation of Amp)

Power System (MPESS)

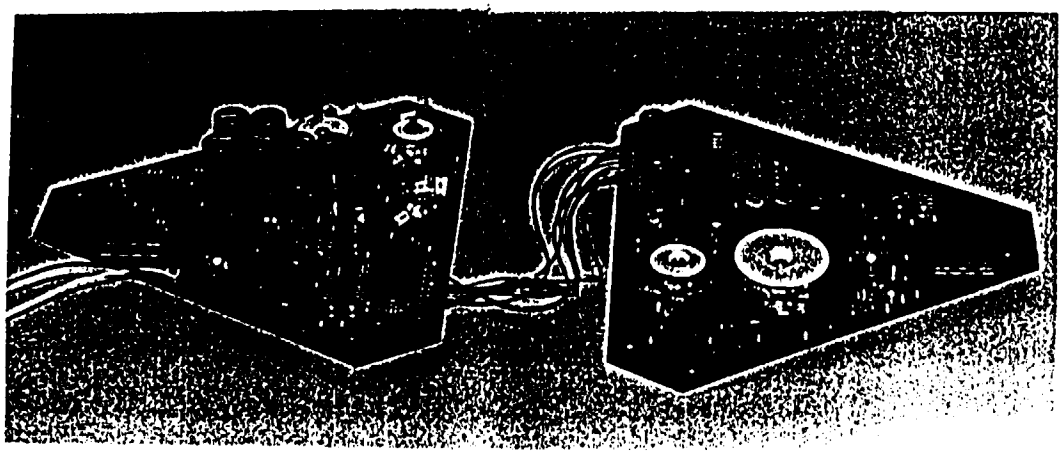


Note: Drawing Not to Scale

- Five 60V/5A supplies for AMED reaction wheel motor supplies
- Two 28V/4A supplies for motor controllers & Power regulator primary
- One ±15V, 5V supply for Mux power
- Line power for BMT/TDS electronics
- Power Connector Panel to route power from supplies to boom cables

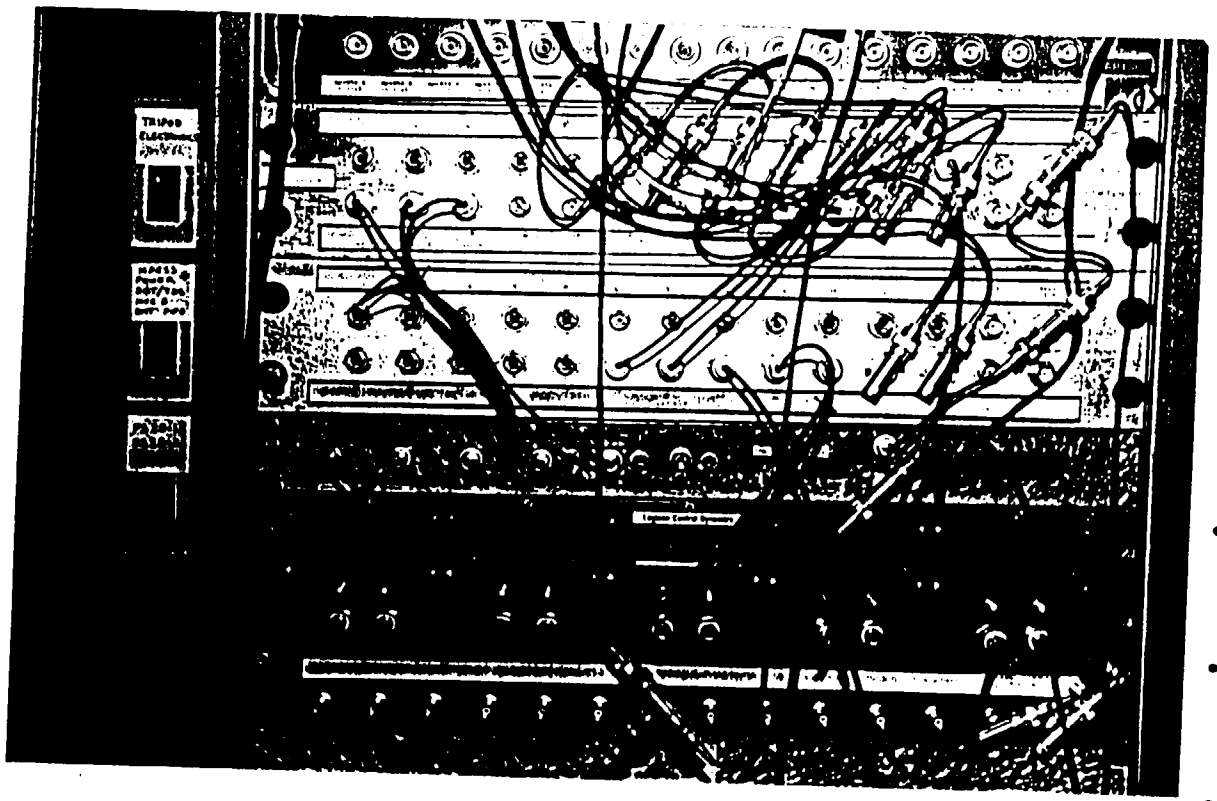
AMED Angular Momentum Exchange Device
BMT/TDS Boom Motion Tracker/Tip Displacement Sensor
MPESS Mission Peculiar Experiment Support Structure

Power Regulation System



- Supplies power to boom-mounted electronics & sensors & actuators at mid-boom & boom tip
- Converts +28 V (from MPESS supply) to ±15 V, +7.5 V, and +5 V for boom electronics
- Sequences the ±15 V and + 7.5 V for the gyro power-on
- Designed by EB-12 and Fabricated & Integrated by CDy

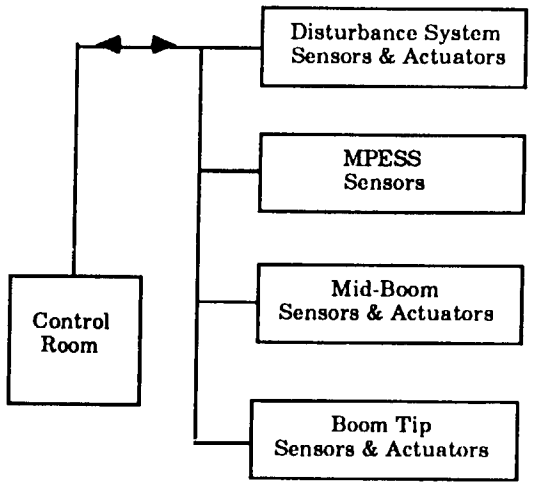
Power System Progress



- Add 28 V supply for tripod sensors
- Integrate 2 power regulation systems with boom electronics
- Add tip Jones strip to tip power reg system & recable
- Send 7 supplies to Lambda for repair
- Implement temporary 60 V supply system on MPESS
- Reintegrate Lambda supplies with MPESS
- Add remote switches for surge suppressors on tripod & MPESS; Allows remote power-on from CR

CR Control Room
MPESS Mission Peculiar Experiment Support Structure

Signal Processing Overview



- Components:

  Mux/Demux Systems (7):
  Debug Systems (5)
  Auto-Cutoff System/Sync Gen
  Real Time Control Computer
  SMS Computer & DAS
  Dell Computer & DAS
  Power System

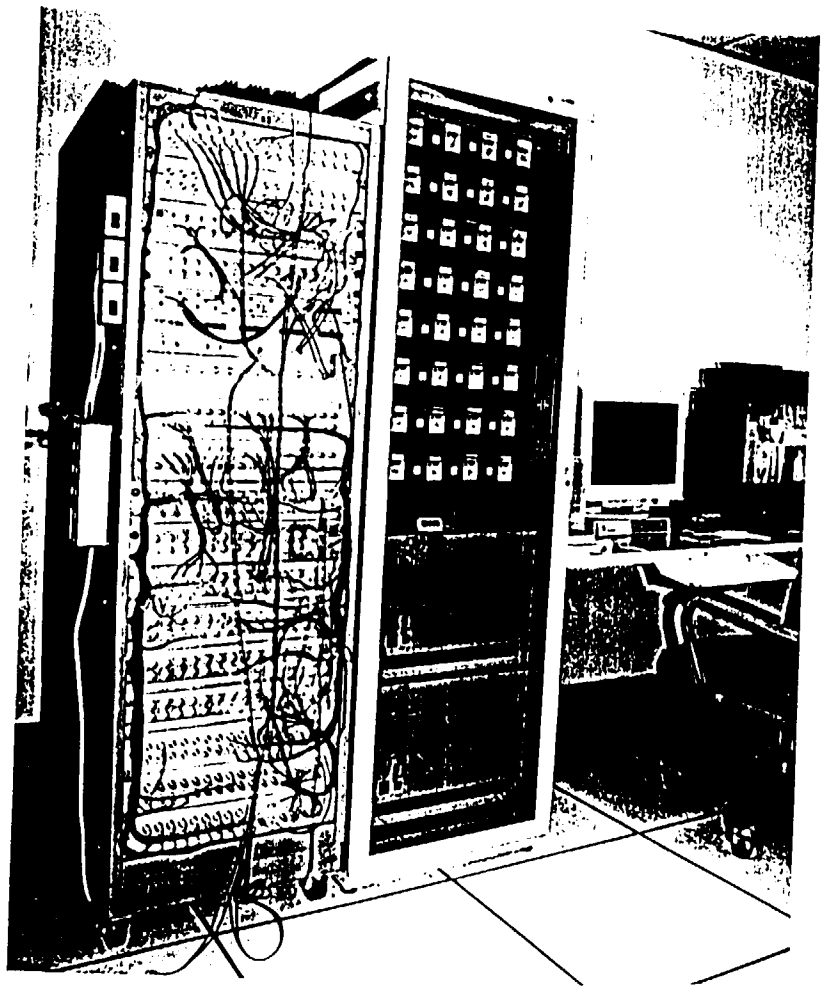
- Electronic Rack provides signal access & signal routing to/from components

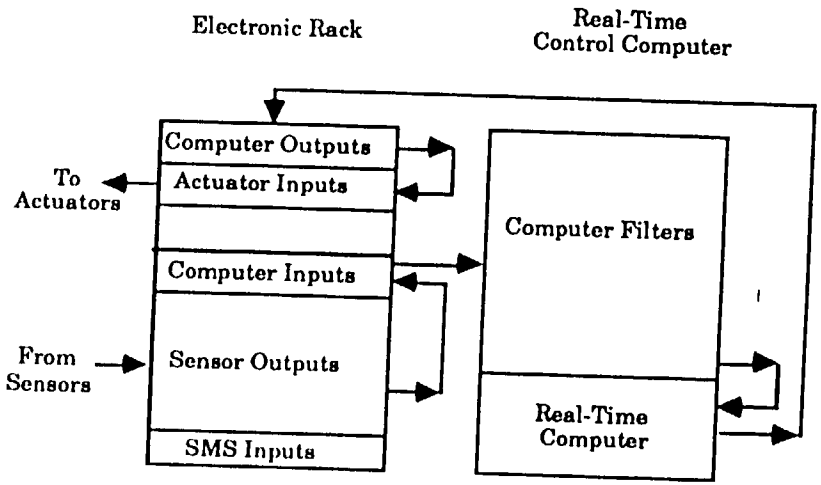
- Locations: Control Room, Tripod, MPESS, Mid-Boom, Boom Tip

- Longest communication distance = 350 feet

Signal Processing: RTCC

- RTCC Inputs from Demux outputs (Sensor Mux's)
- RTCC Outputs to Mux inputs (Actuator Mux's)





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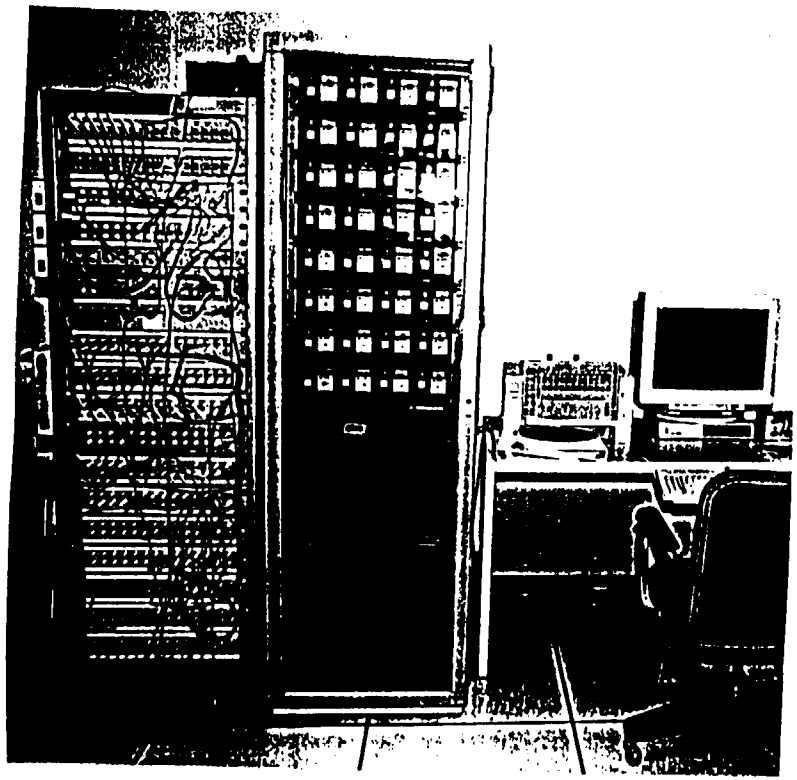
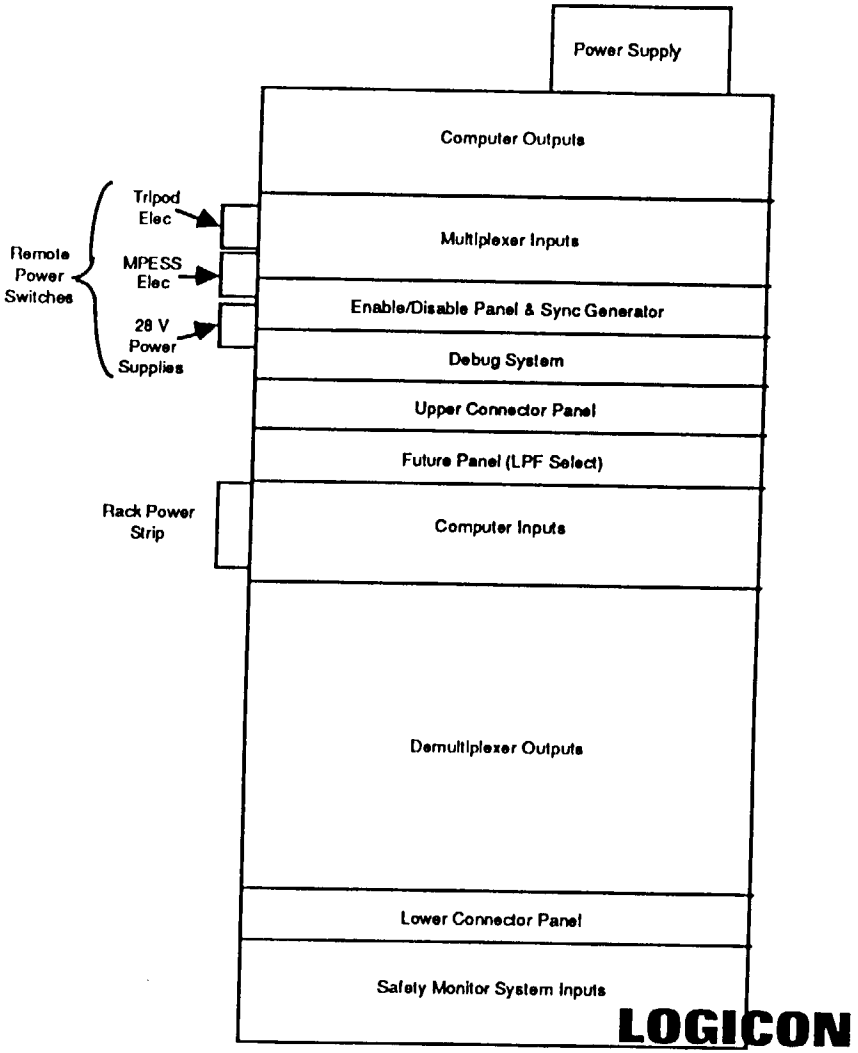
Control Dynamics

Signal Processing: Electronic Rack

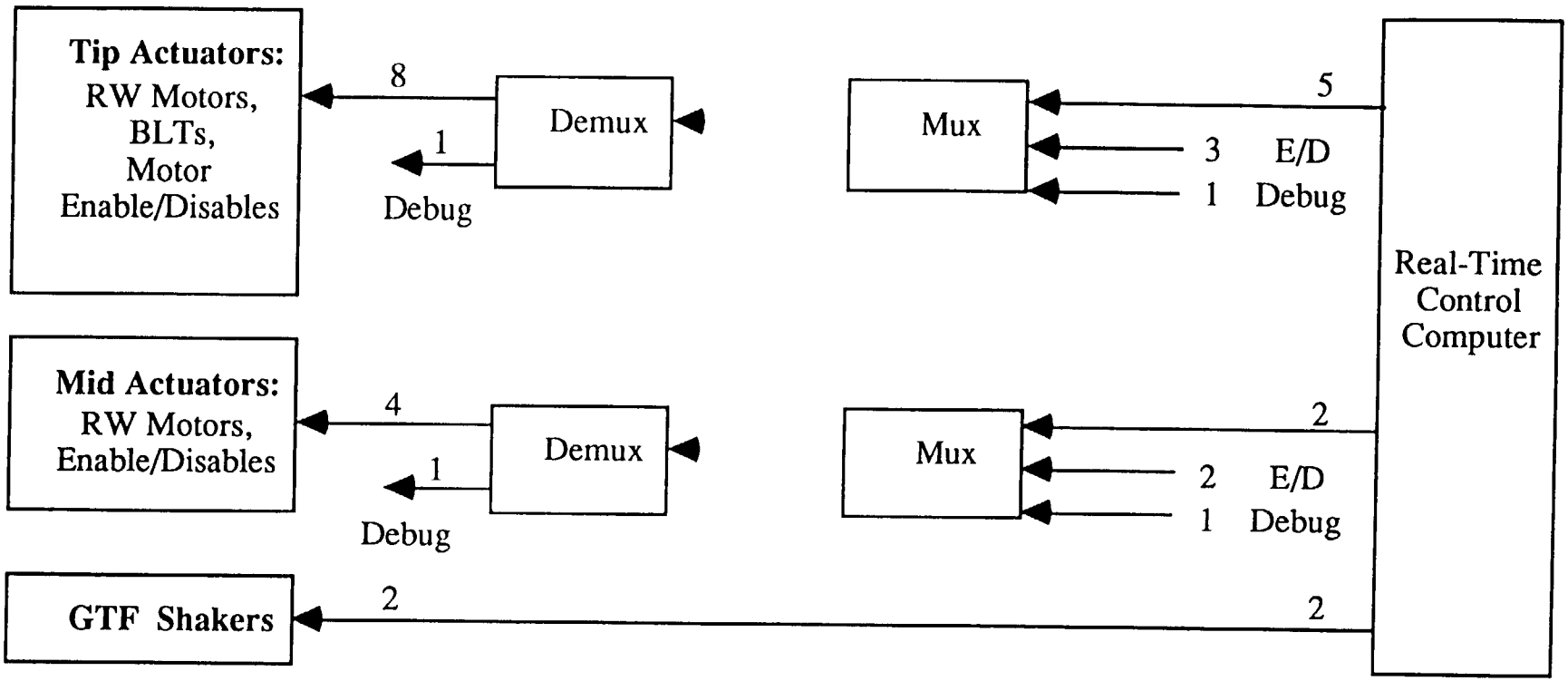
- Rack serves as patch panel between RTCC, SMS, Mux's, Demux's, Debug, Auto-Cutoff

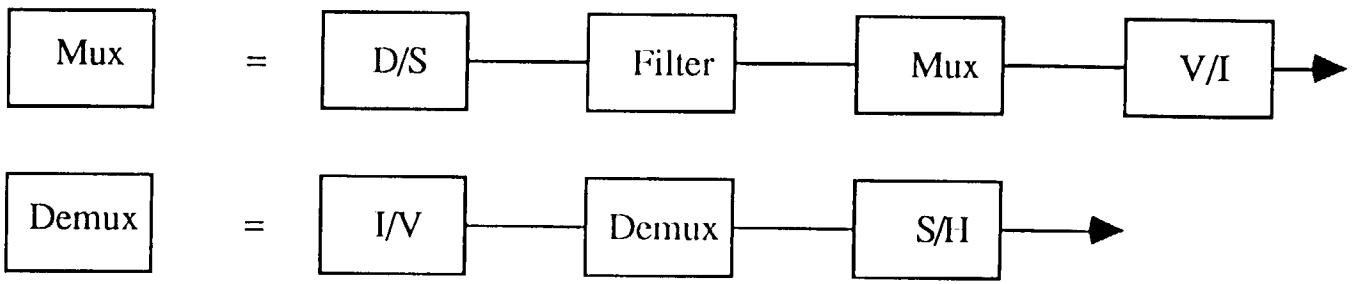




RTCC Real-Time Control Computer

CASES GTF Signal Processing: Actuators

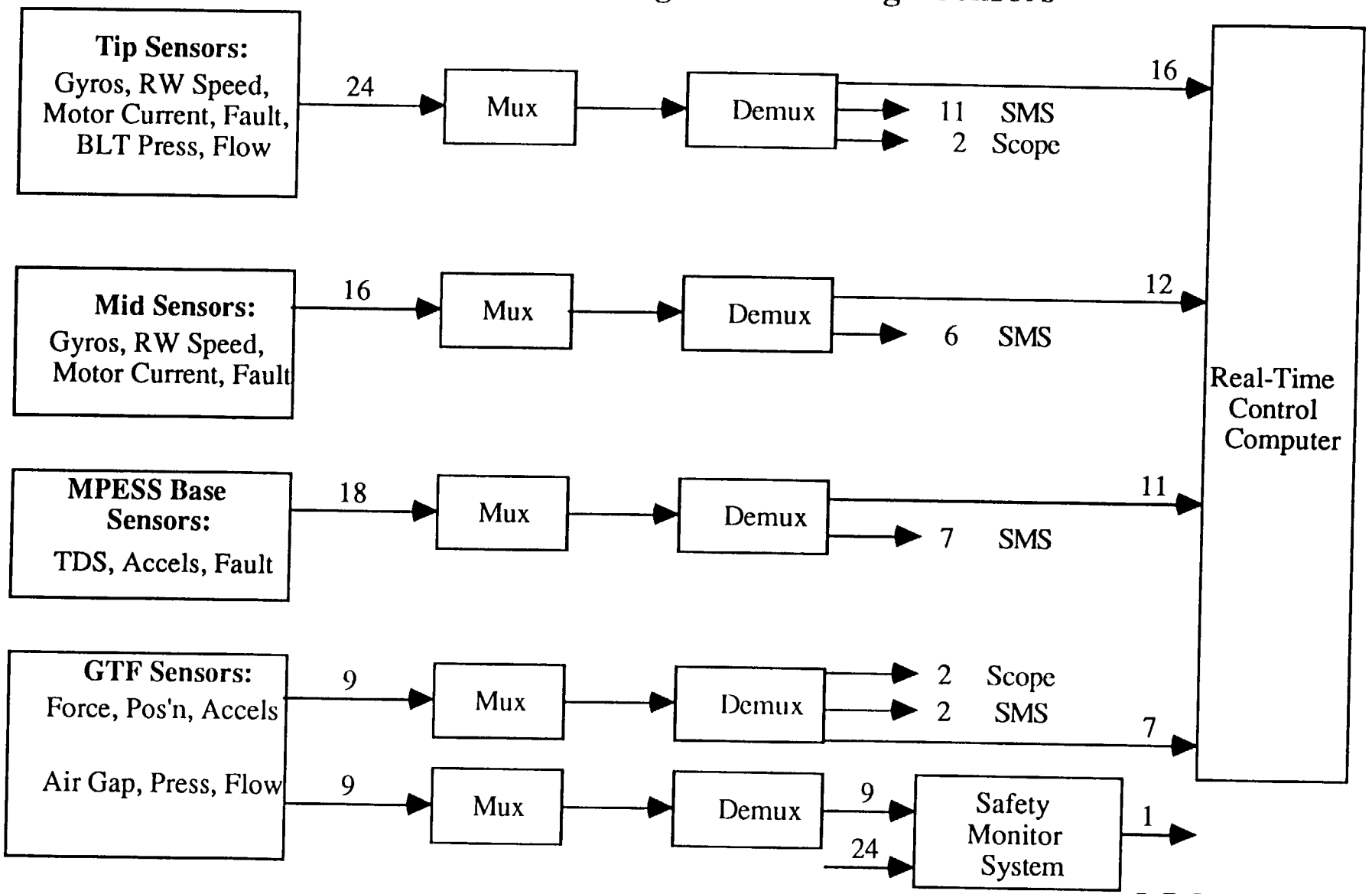




LOGICON

Control Dynamics

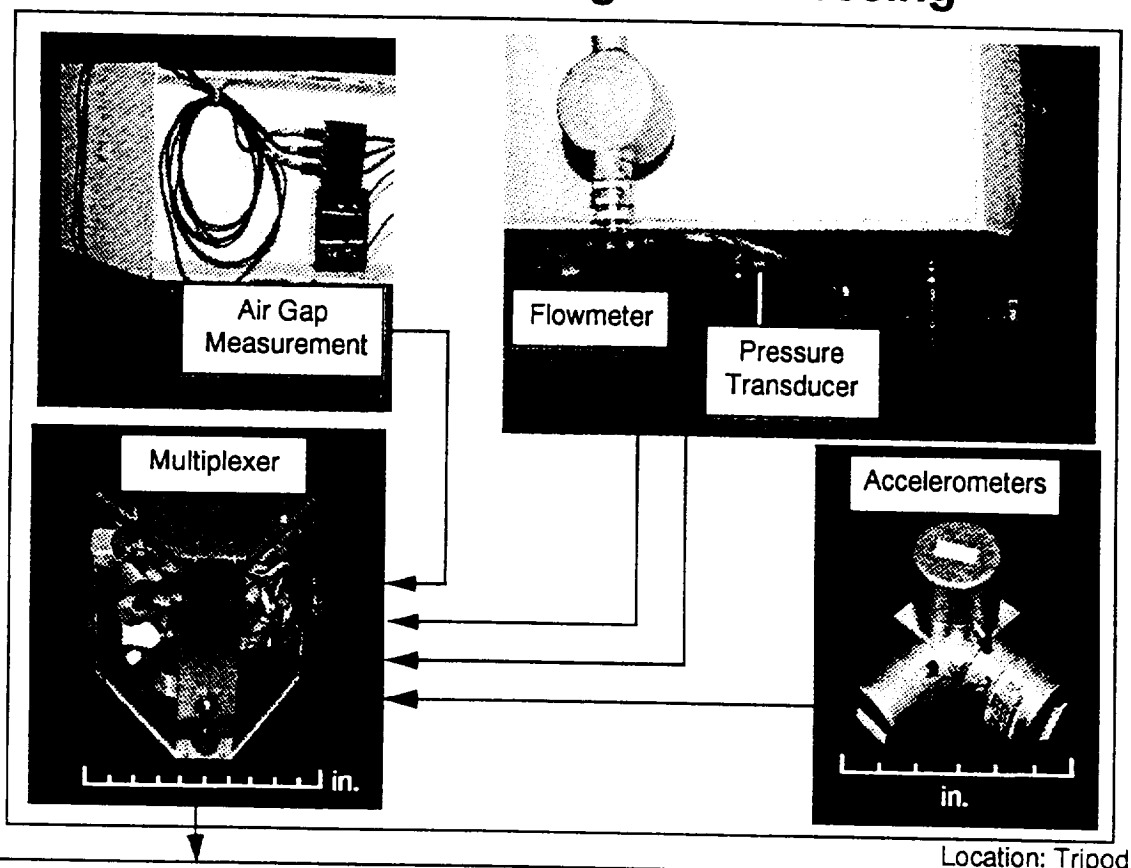
CASES GTF Signal Processing: Sensors



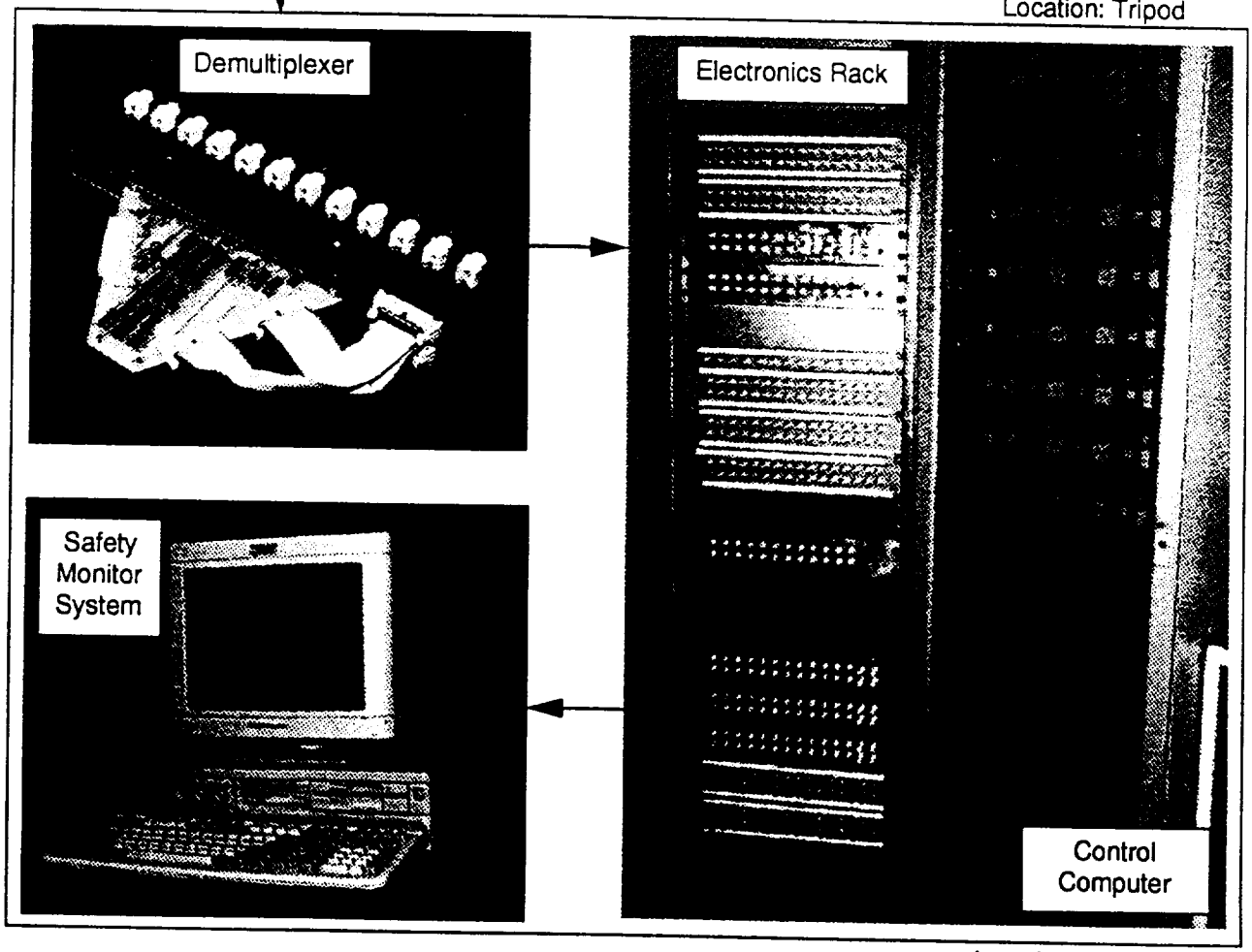
LOGICON

Control Dynamics

Cases Sensor Signal Processing



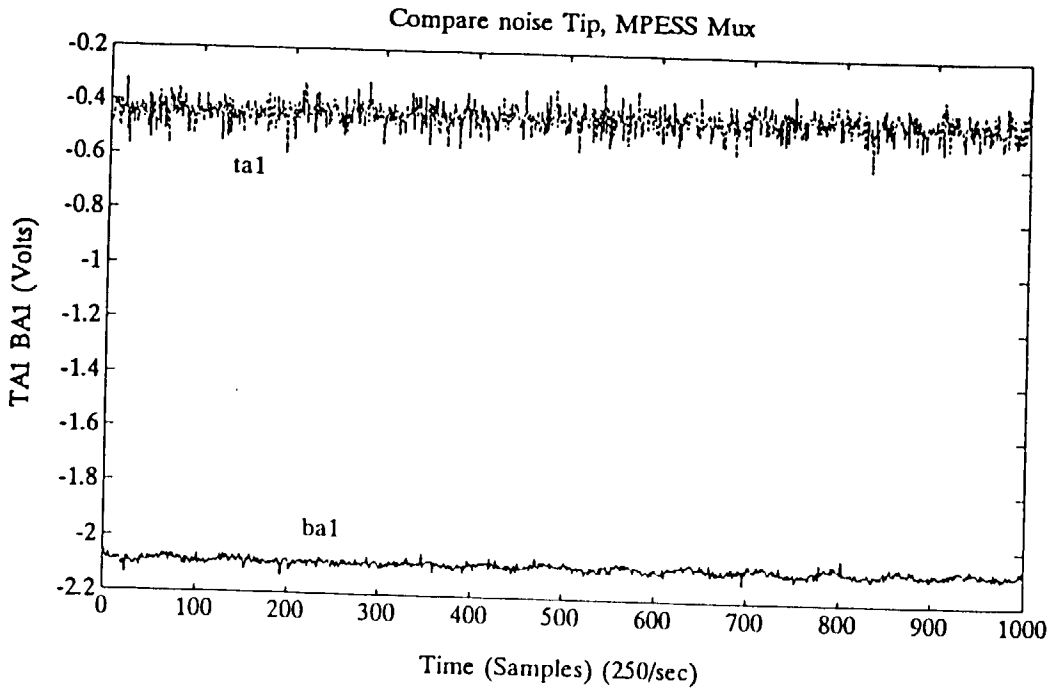
Location: Tripod



Location: Control Room

Multiplexer Tests: Noise Comparison

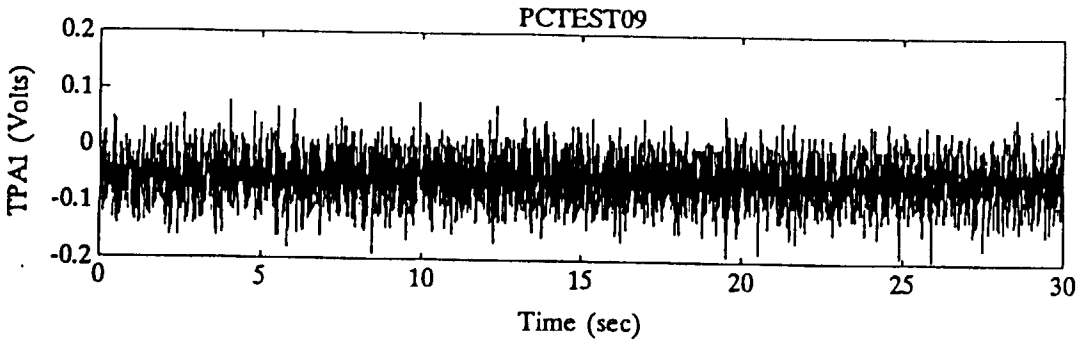
- Perform Preliminary Mux/Demux testing: Compare noise levels from various M/D's
- Quiescent test in Volts (Compare accelerometer noise at MPESS & Tip)
- Discover tip Mux is noisier than other Mux's



Multiplexer Tests: Noise Comparison

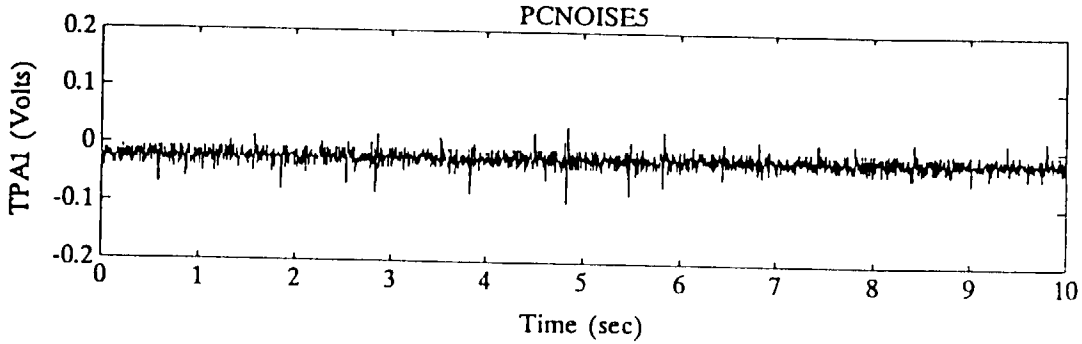
- Modify shields, Change capacitor in Demux board, Add di/dt limiter to sync generator
- Examine thruster test point signals to evaluate effect of changes

Note improvement of noise by factor of 5 or 10



Quiescent Test (TPA1)

Before



After

Signal Processing Summary

- Implementation, Integration & Testing by: CDy, ED-73
  Designs by: CDy, EB-22, EB-12, ED-73

- Signals routed to & from RTCC, SMS, M/D's, Auto-Cutoff, Debug systems

  Signals, Wires, Cables, Connectors prepared, labeled, installed & verified

SMS:	34 inputs & 1 output	Auto-Cutoff:	6 inputs/6 outputs
RTCC:	46 inputs & 9 outputs	Debug System:	82 inputs/5 outputs
M/D's:	82 inputs/outputs		

- Debug System developed, integrated & tested

- Auto-Cutoff System developed, integrated & tested

- Mux/Demux Systems (7) tested & operational
  Mux/Demux power systems operational

- Power Regulation System (3) operational

Signal Processing: Future Recommendations

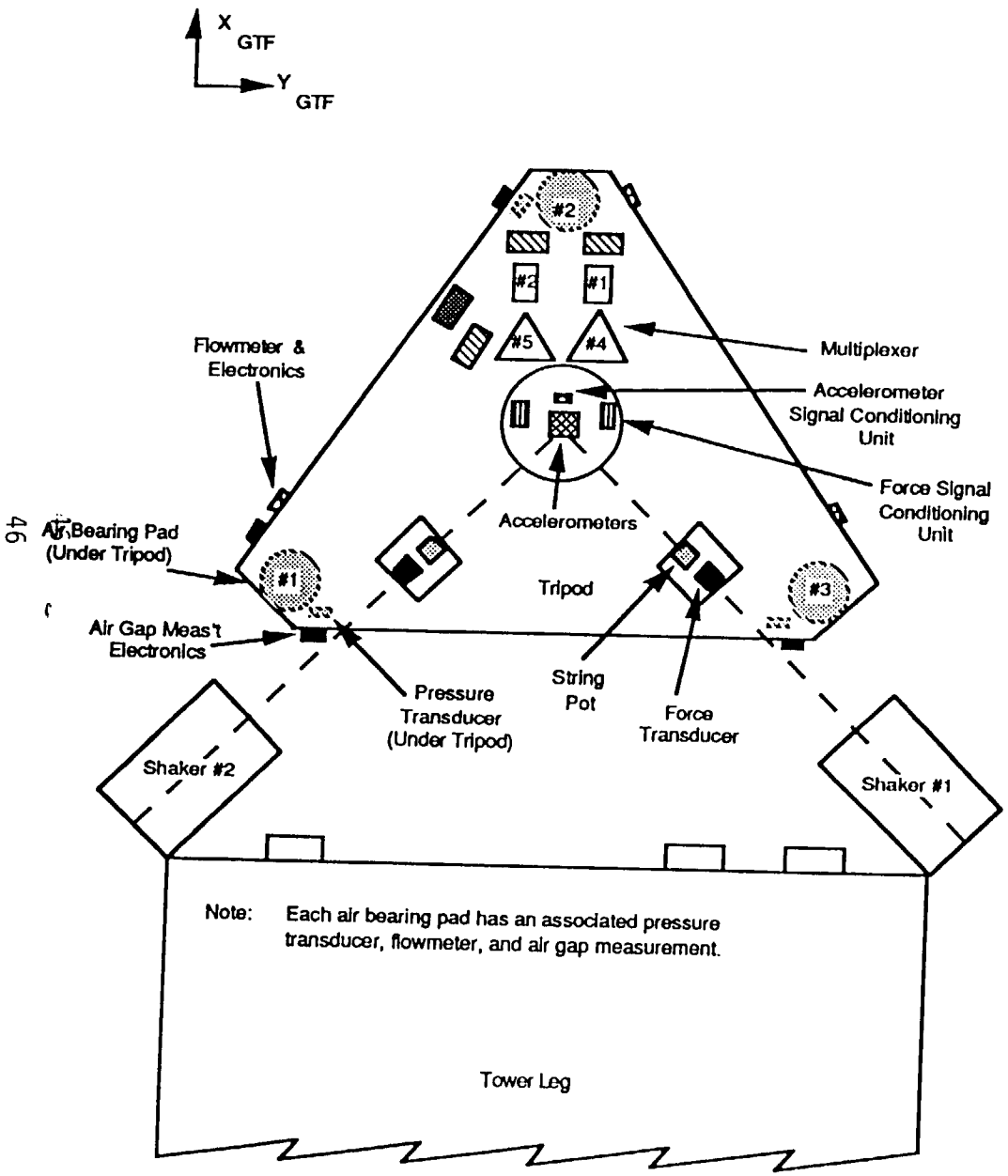
Recommended Upgrades	Benefits
Refine Mux/Demux system (Add sync detector ckt)	M/D failure can cause large actuator commands
Replace Lambda 60 V supplies	Eliminate power supply failures
Miniaturize Mux/Demux & Filtering system	Decrease weight of electronics on boom More flight-like hardware
Investigate possibility of deployeable & retractable PC board fixtures	Ability to deploy & retract boom electronics

M/D Multiplexer/Demultiplexer

3.4 Sensors & Actuators

This section discusses all the sensors and actuators located on the CSI/CASES facility: the disturbance system, the AMEDs, the BLTs, the BMT/TDS, and other associated sensors. Each sensor and actuator is depicted and the respective location on the facility explained. Sensor and actuator characteristics are also provided. Recommended upgrades are listed at the end of the section.

DS Sensors & Actuators



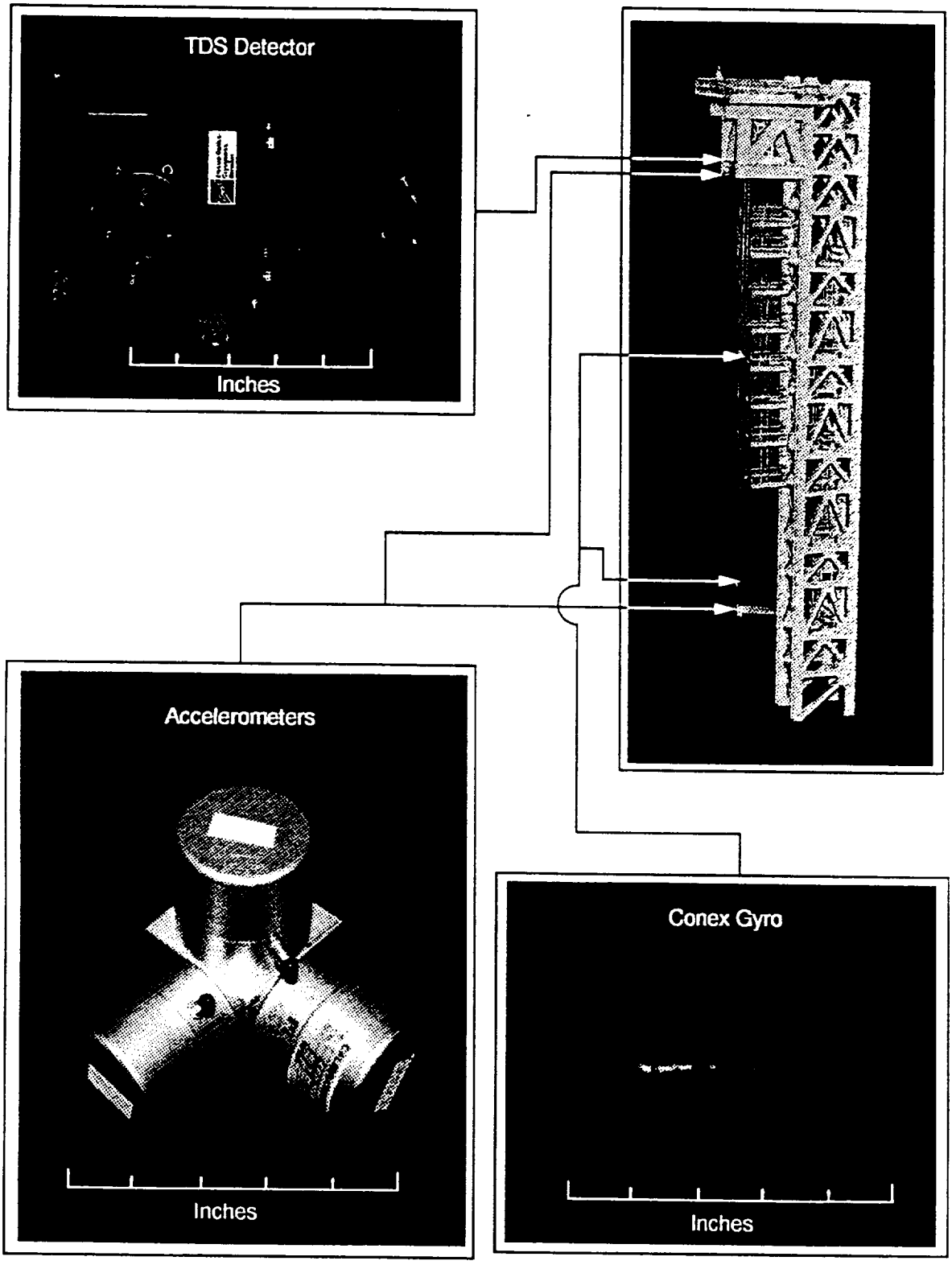
Note: Drawing not to Scale

- Dynamic Sensors: Force, Accel, Position
- Air Bearing Sensors: Gap, Press, Flow
- Actuators: Shakers

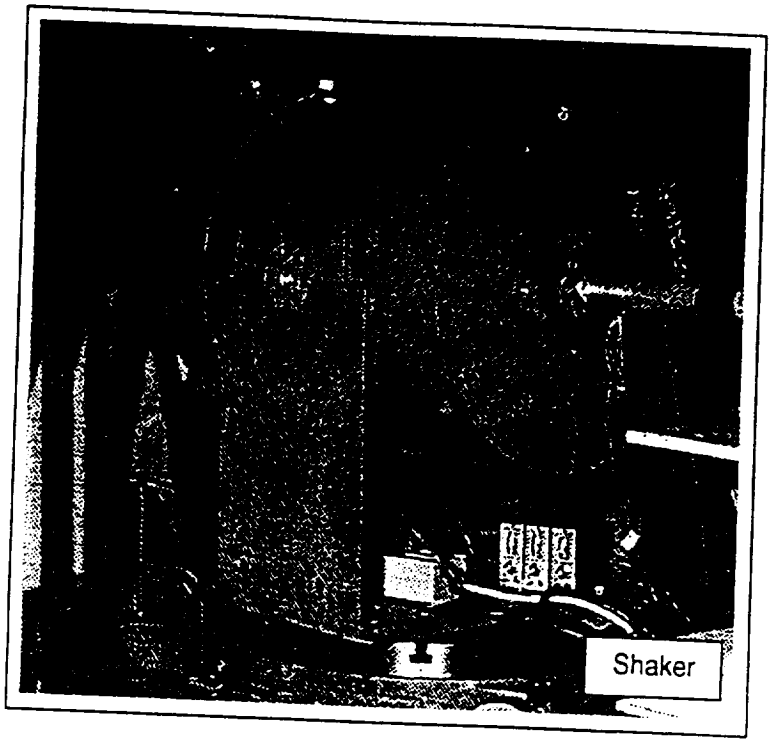
LOGICON

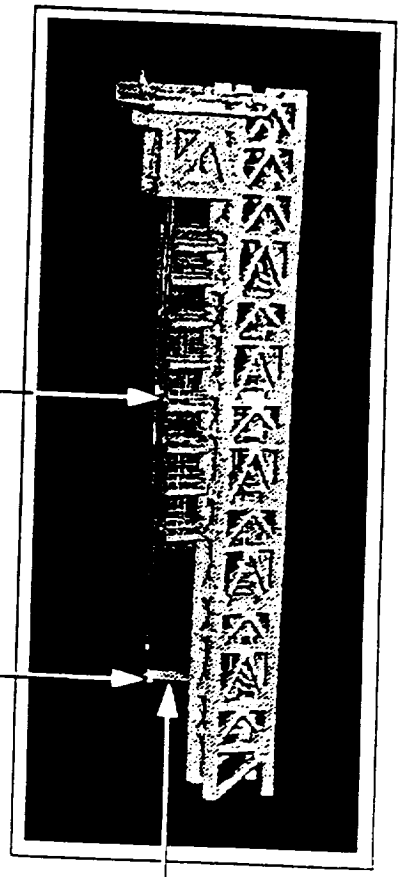
Control Dynamics

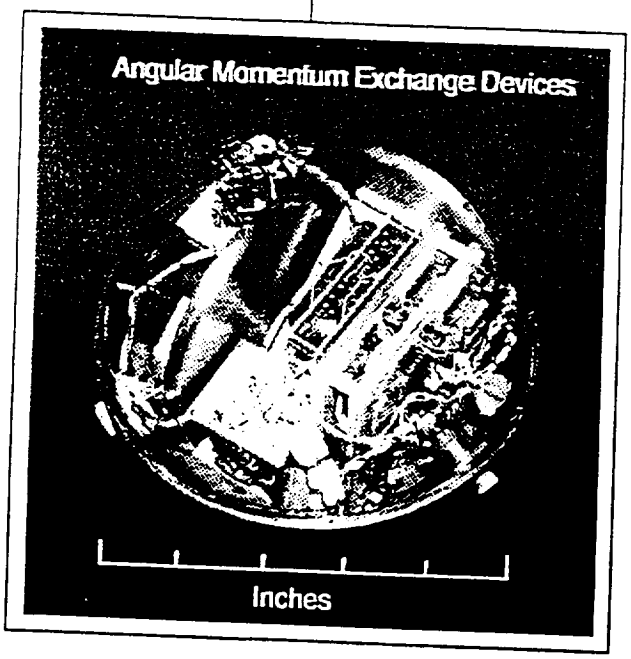
CASES Control Sensors

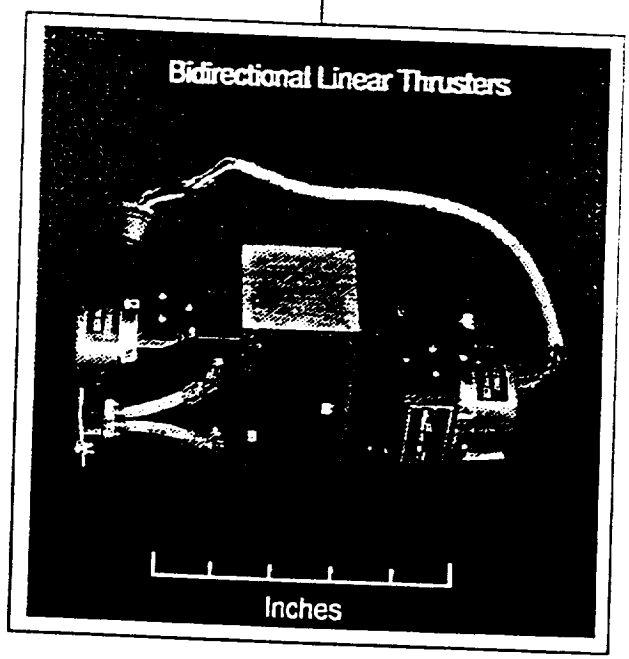


CSI Actuators

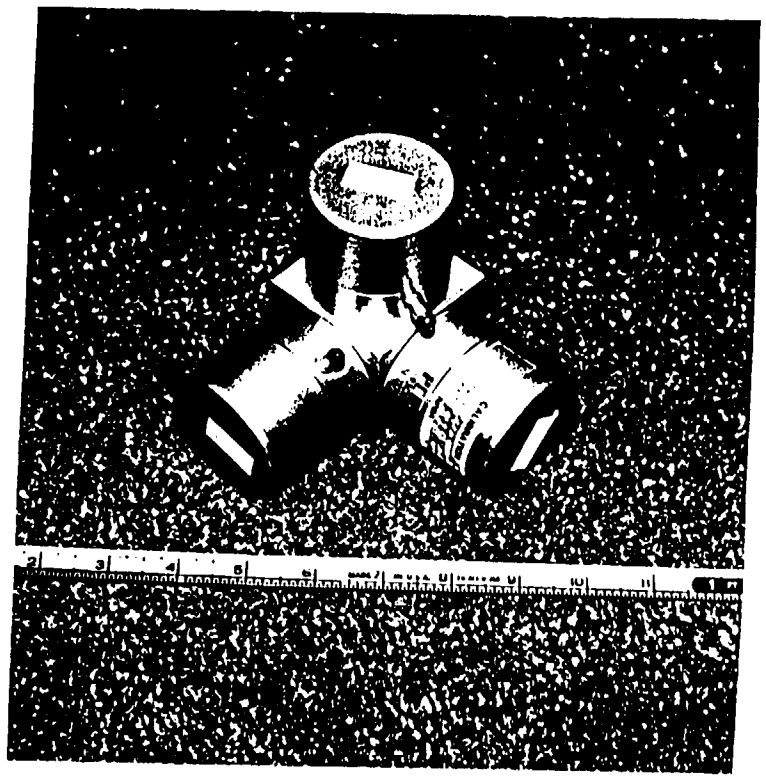








Sensors: Accelerometers (PCB)



- 3 orthogonal 1-axis seismic accelerometers

  Located at: Tripod
  MPESS
  Tip Plate

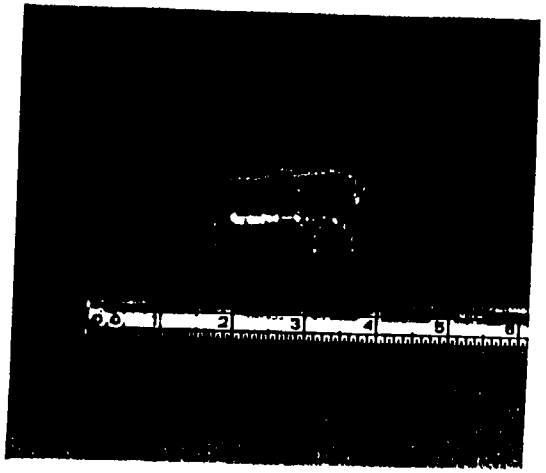
- Frequency Range: 0.025 - 800 Hz
- Weight: 2.2 Lbs each

Activities:

- Accels aligned & mounted onto MPESS, Tripod & DS
- Accel power units interfaced with power regulation system
- Accelerometer gain (50) incorporated (via DtoS boards)

DS Disturbance System
DtoS Differential to Single Ended converter/amplifier
MPESS Mission Peculiar Experiment Support Structure

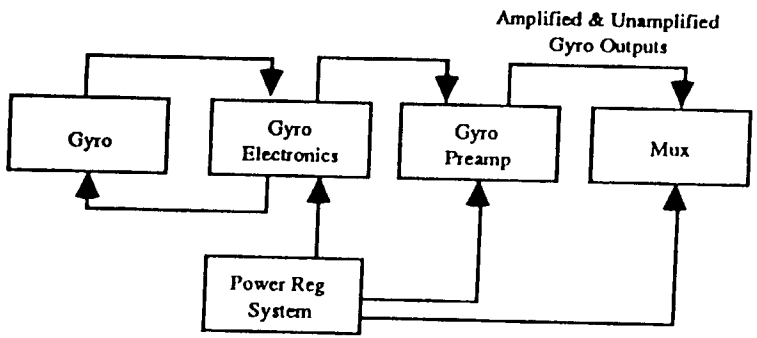
AMED Sensors: Gyros (Kearfott)



- 2 orthogonal dual-axis gyros in each AMED

  Located at: Mid-Boom & Boom Tip

- Bandwidth: 100 Hz
- Weight: 0.3 Lb

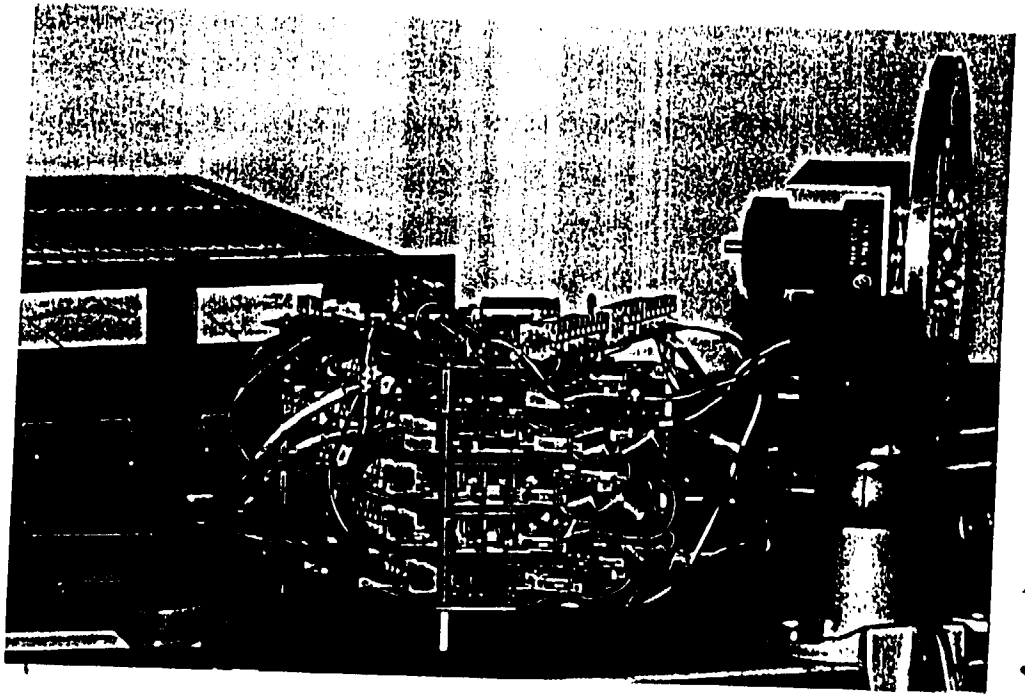


Activities:

- Gyros interfaced w/ Mux & Power Reg Sys
- Modified Gyro Preamps (gain: 150 to 30)
- Modified LPF cutoff for gyro channels
- Replaced one tip gyro (failure)
- Functionality testing: verified signs
- Utilized gyros in system ID testing

AMED Angular Momentum Exchange Device
LPF Low Pass Filter

AMED Actuators: Motors (Inland)



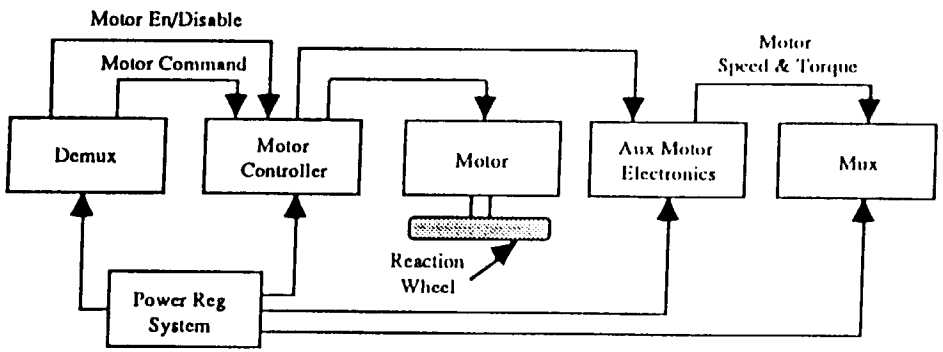
- 2 orthogonal DC brushless motors per AMED

  Located at: Mid-Boom & Boom Tip

- Bandwidth: 1000 Hz
- Weight: 0.8 Lb
- Torque: ± 135 oz-in

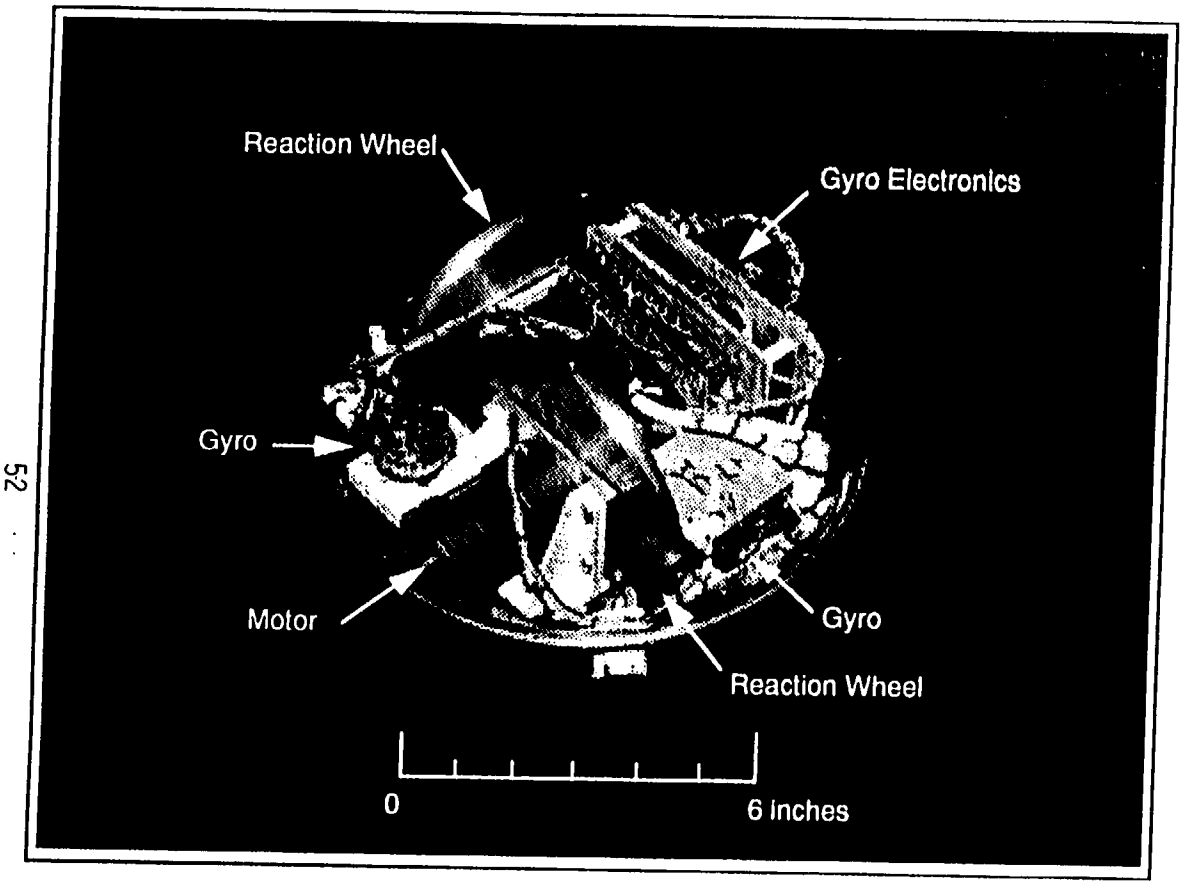
Activities:

- Attempt to improve wheel/shaft interface
- Interfaced w/ Demux & Power Reg Sys
- Perform sanity checks on wheel torque command, speed, current
- Replaced one motor speed board (failure)
- Utilized motors in system ID testing



AMED Angular Momentum Exchange Device

Angular Momentum Exchange Devices (AMEDs)



- Each AMED package includes:

  2 DC brushless Inland motors

  2 dual axis Kearfott Conex gyros (with electronics)

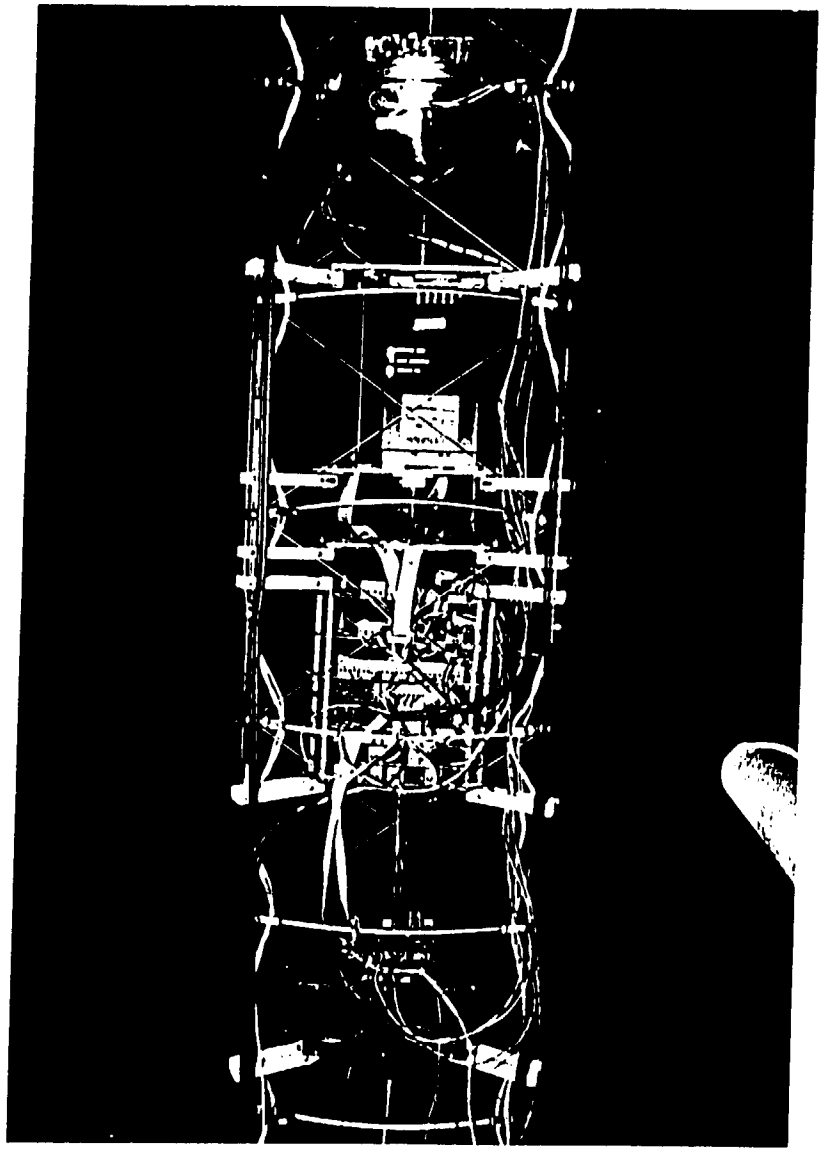
- Located at: Mid-Boom & Boom Tip
- Weight: 13 Lbs
- AMED package is retractable; Present motor, power, M/D electronics are not retractable

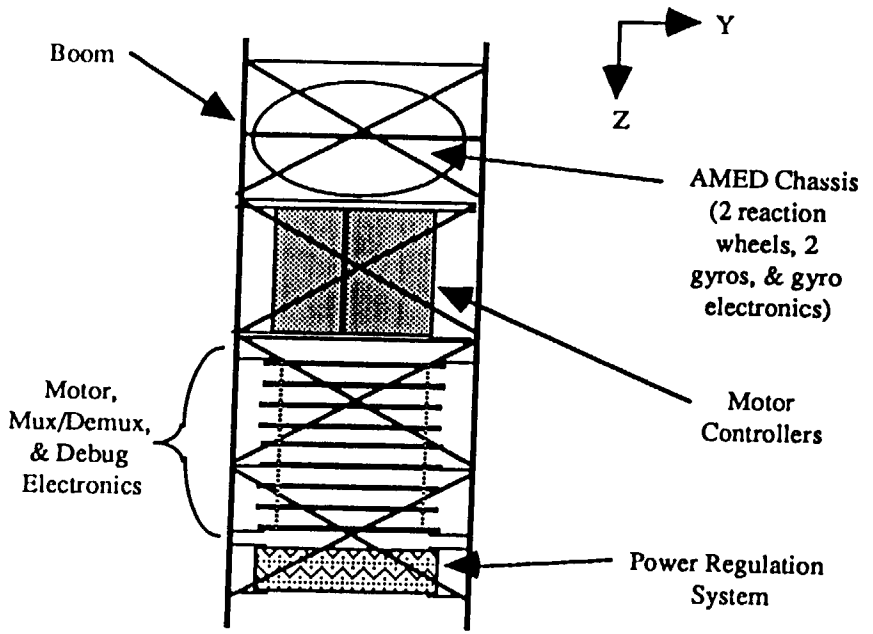
Activities:

- AMED Testing in-place: Functionality & System ID Tests
- Interfaced w/ Mux/Demux (M/D) & Power Regulation System

ID Identification
M/D Multiplexer/Demultiplexer

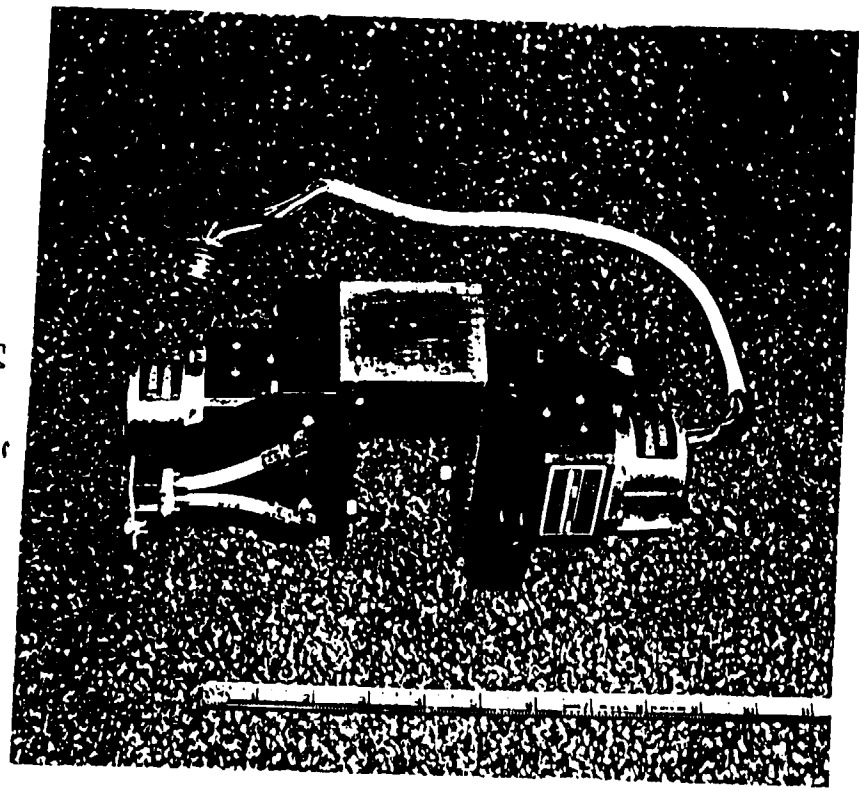
Mid-Boom AMEDs





Note: Drawing not to Scale

Bidirectional Linear Thrusters (BLTs)

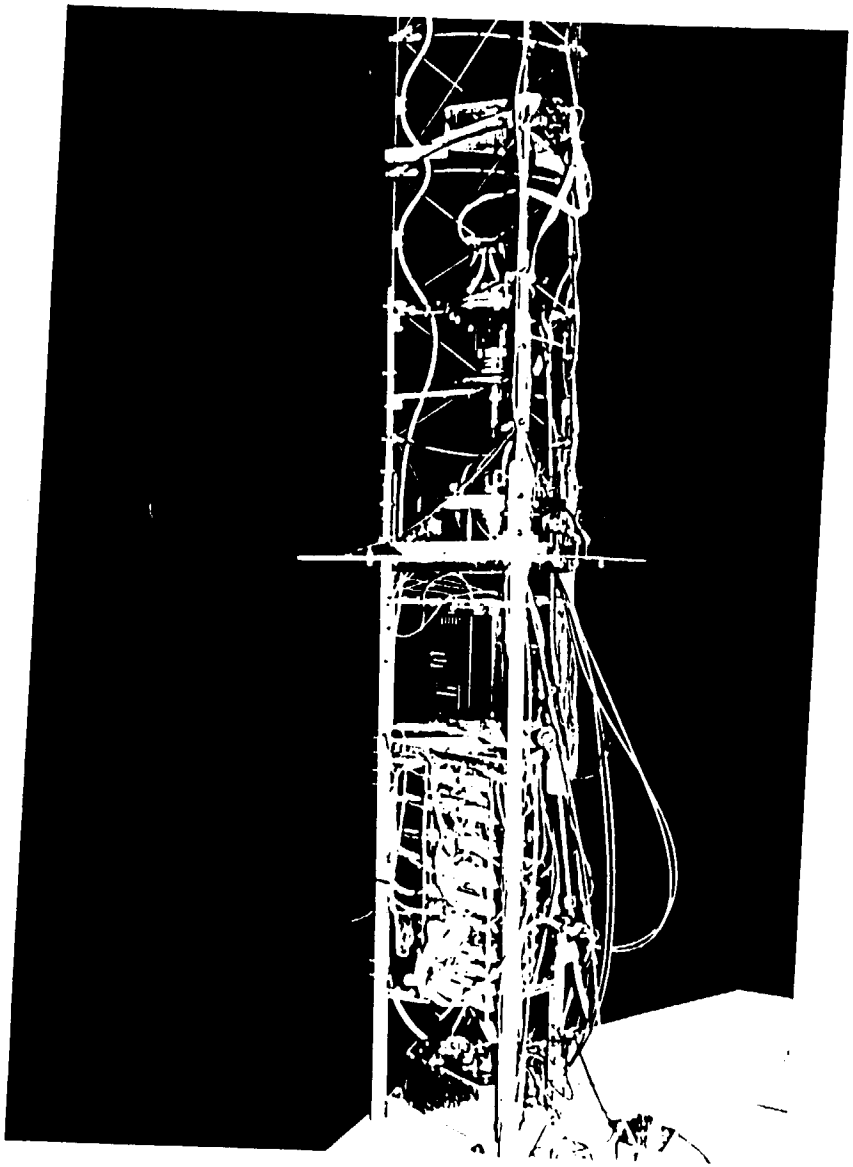


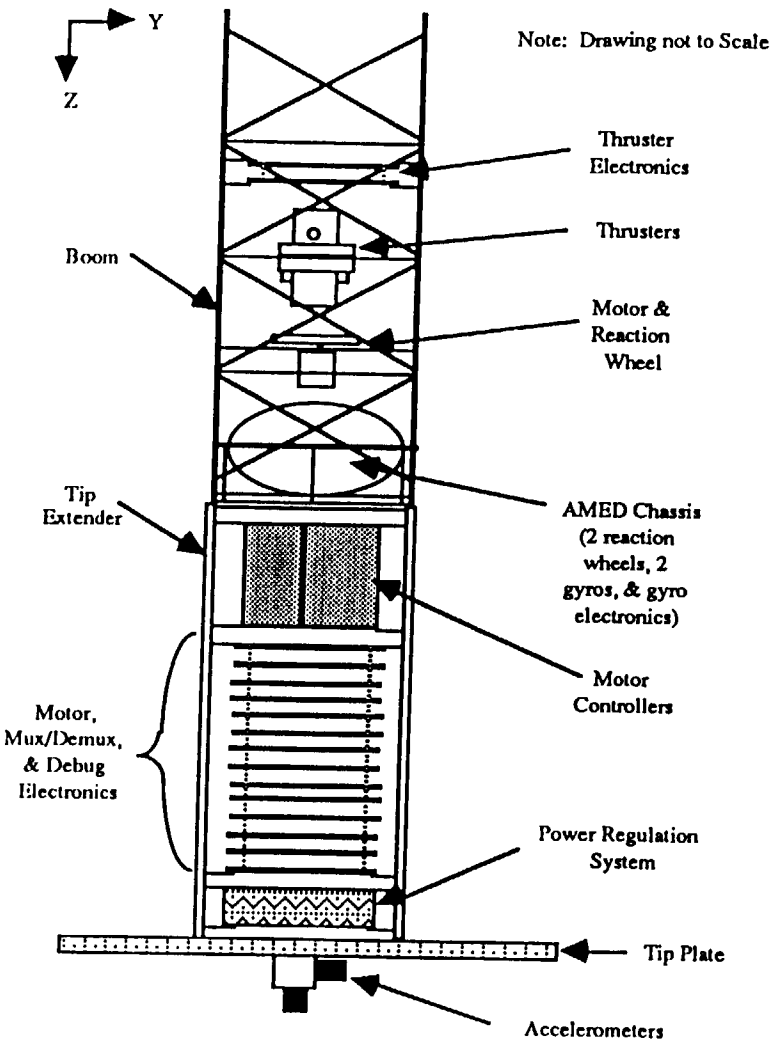
- 2 Orthogonal Boeing Thrusters located at Tip
- Force Range: ± 2 lbs-f (Linear)
- Weight: 4 lbs
- Bandwidth: 70 Hz (Boeing Freq Response)
  Phase lag is -120 deg at 70 Hz

Activities:

- Add pressure transducer to tip
- Add flow straightener to tip
- Replace defective chip on BLT elec PC board
- Interface BLT Test Points with Mux
- Perform BLT characterization tests
- Perform system ID tests with BLTs

Boom Tip (AMEDs & BLTs)

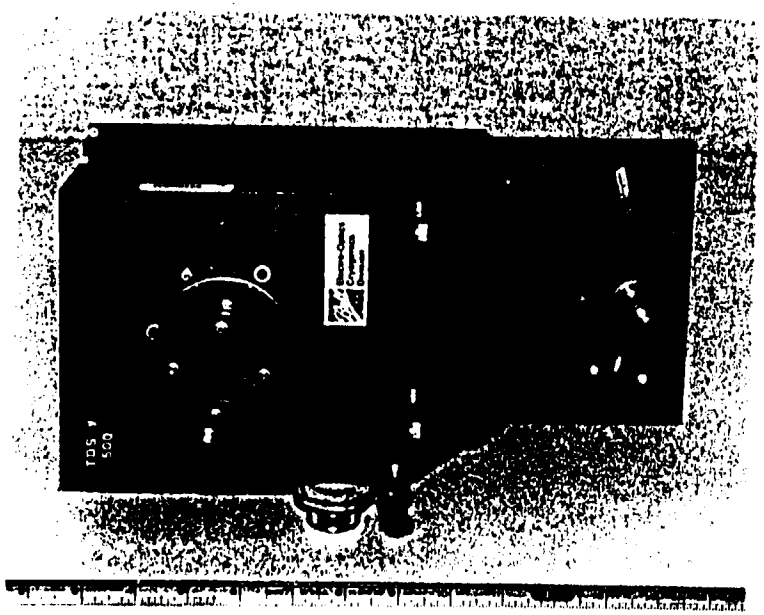




LOGICON

Control Dynamics

Tip Displacement Sensor (TDS)
Ball Aerospace



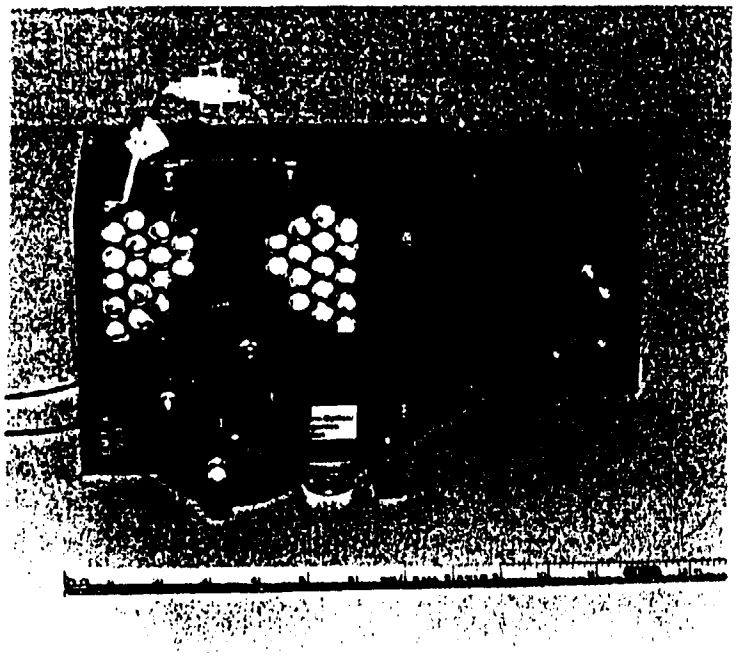
- Closed Loop Sensor: Control Sensor

  Open Loop Sensor: Augments BMT data for System ID

- Measures disp of tip targets
- Two CCD detectors (X,Y) mounted on MPESS
- Four LED targets on tip plate
- Processes 4 targets at up to 500 Hz
- Travel Range: (-15, +15) inches
- Accuracy 0.01 inch

BMT	Boom Motion Tracker	CCD	Charge Coupled Device
LED	Light Emitting Diode	ID	Identification
MPESS	Mission Peculiar Experiment Support Structure		

Boom Motion Tracker (BMT)
Ball Aerospace



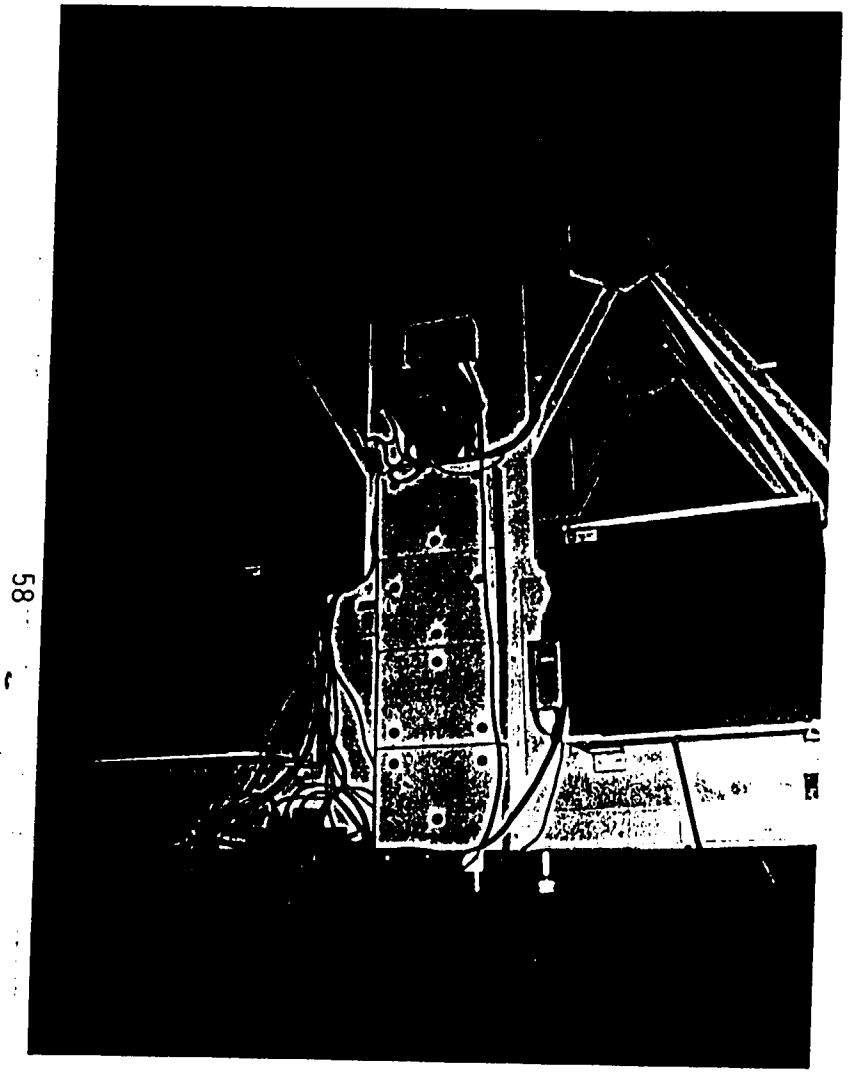
- Optical system for measuring boom displacements
- Open Loop Sensor: System ID/Modeshape Meas't
- Measures angular disp of boom targets
- Three CCD detectors (X,Y,Z) mounted on MPESS
- LEDs on MPESS to illuminate targets
- Passive Targets made from reflective tape
- Processes 37 targets at 100 Hz
- Travel Range: (-10", +10") at boom tip
  (-4", +4") at boom base
- Accuracy 0.01 inch

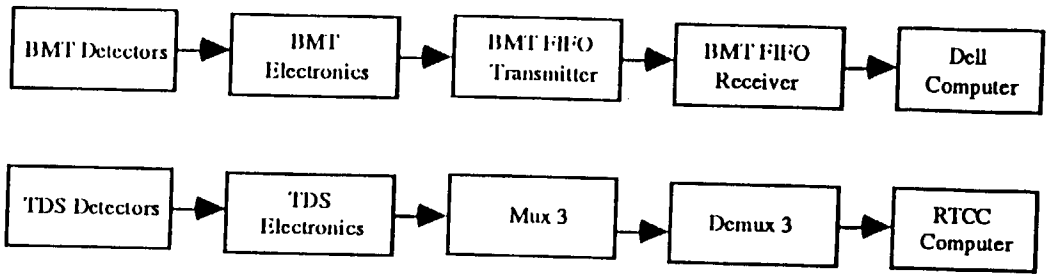
BMT	Boom Motion Tracker	CCD	Charge Coupled Device
LED	Light Emitting Diode	ID	Identification
MPESS	Mission Peculiar Experiment Support Structure		

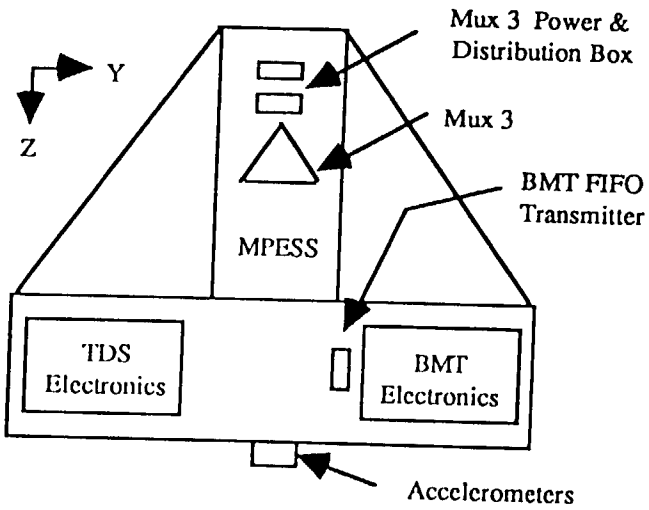
LOGICON

Control Dynamics

BMT/TDS Interfaces







Note: Drawing Not to Scale

BMT Boom Motion Tracker
MPESS Mission Peculiar Experiment Support Structure
TDS Tip Displacement Sensor
FIFO First In First Out

LOGICON

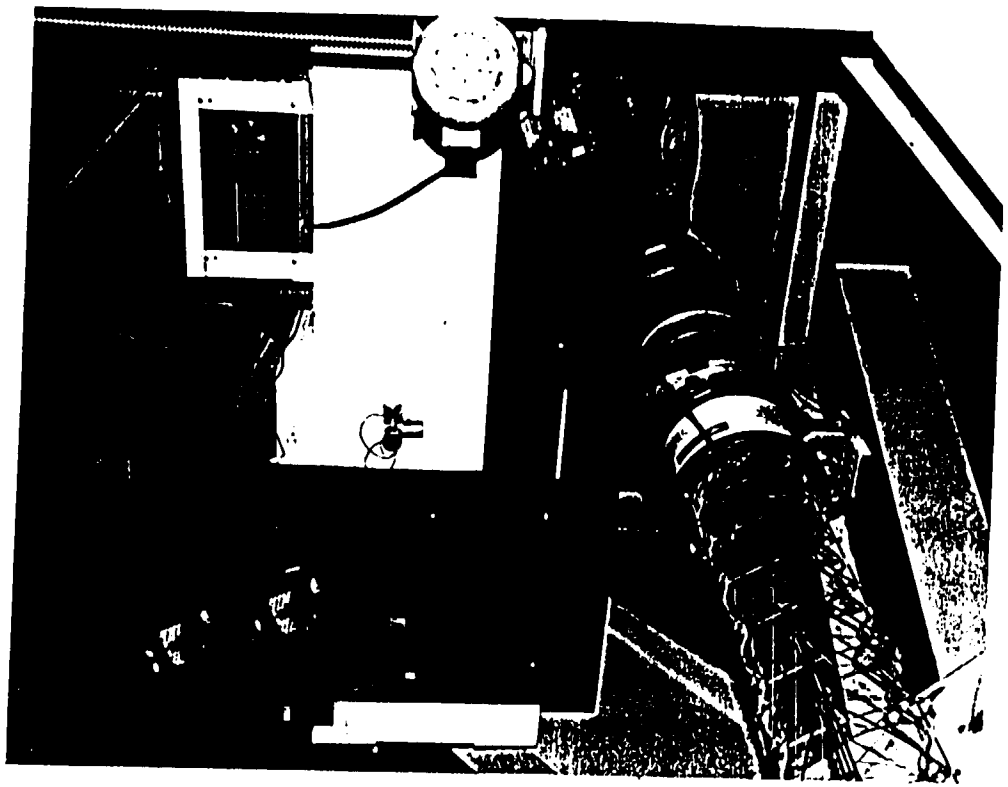
Control Dynamics

BMT/TDS Interfaces

MPESS (Bottom View)

3 BMT detectors (w/Illuminators), 2 TDS Detectors

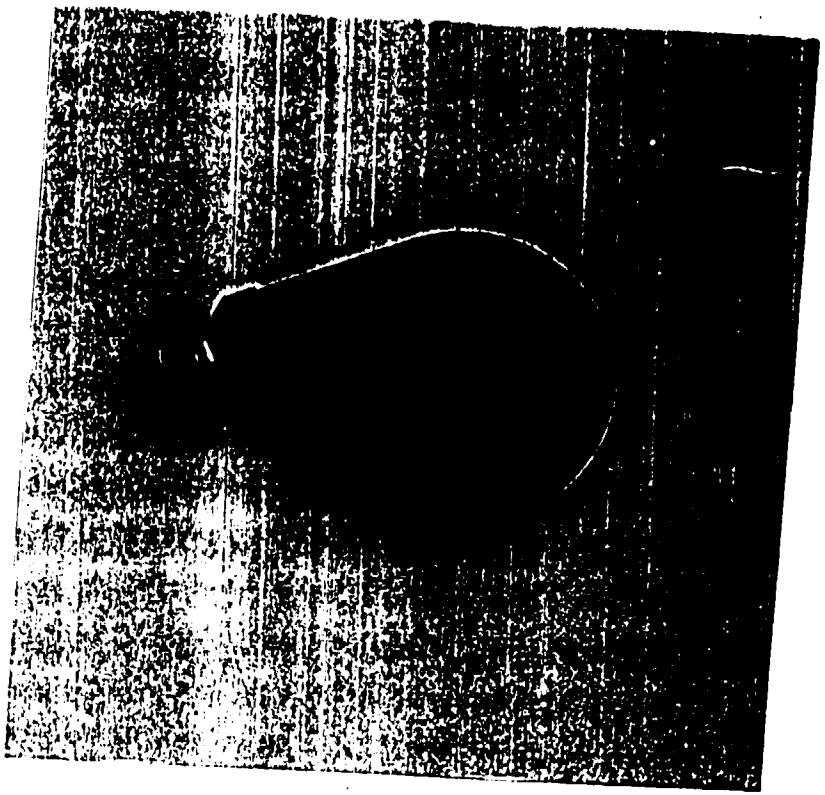
(Accelerometers)



Reflector

Reflective tape on Reflector mount

(Tape replaced with new Tape & Mask)



BMT Boom Motion Tracker
MPESS Mission Peculiar Experiment Support Structure
TDS Tip Displacement Sensor
FIFO First In First Out

Sensor & Actuator: Future Recommendations

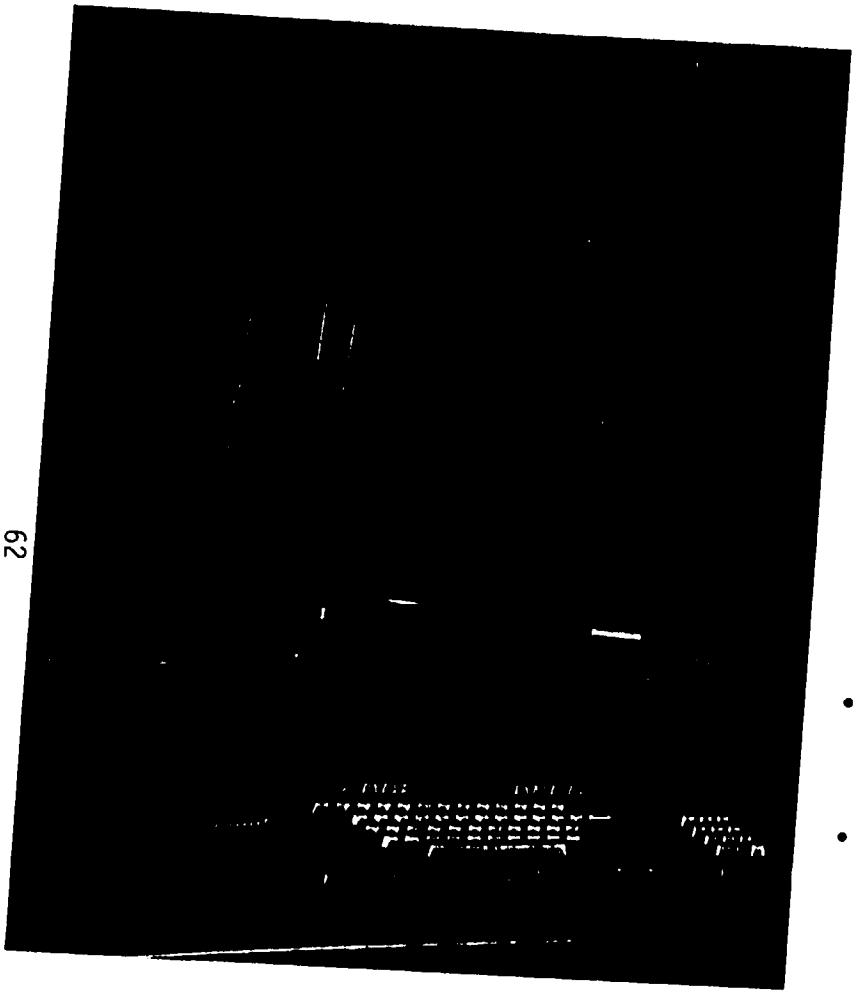
Recommended Upgrades	Benefits
Redesign motor shaft/RW interface	Reaction wheels will be safe Extend allowable Torque & Speed range
Develop TDS spike removal filter	Filter spikes prior to RTCC
Develop software to use BMT	Obtain useful EU data
Test & Evaluate BMT System	Determine BMT limitations, difficulties, ranges of operation, etc...
Develop software to display "animated" run-time displacements (BMT)	Visual display of boom motion
Perform modal test to compare conventional accel modal test with BMT	Dynamic verification of BMT
Fabricate extra AMED system (working RWs) for demonstrations in lab	Provide active AMED demo to visitors Extra available for replacement

AMED Angular Momentum Exchange Device
RW Reaction Wheel
BMT Boom Motion Tracker
TDS Tip Displacement Sensor

3.5 Computer System

This section discusses the development of various components of the CSI/CASES computer system. These components include: the BMT data acquisition computer, the real-time control computer, the safety monitor system, the auto-cutoff system, and the video monitor system. The capabilities of each of the above is described along with their progress. Recommendations are listed on how the computer system could be upgraded in the future.

BMT Data Acquisition System



- Developed by CDy based on Ball Design
- Acquires data from BMT system

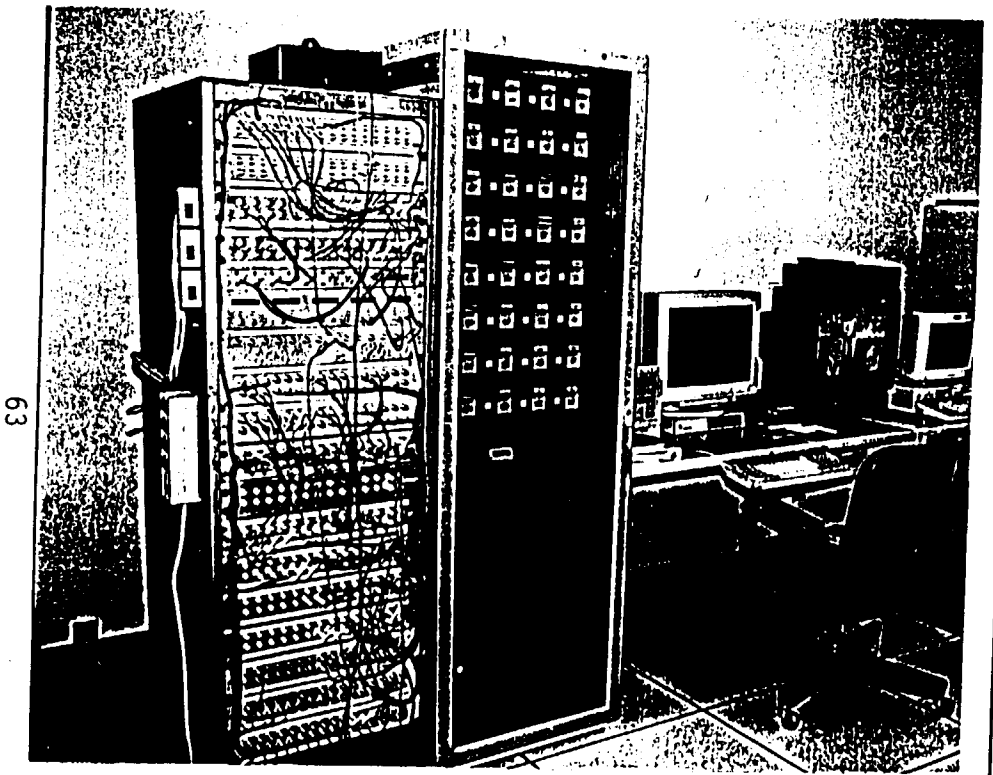
  Reduces peak transfer rate required (4 MB/sec)

  Transfer data at avg O/P rate of the BMT (45 kB/s)

  Transmit data 240 feet (BMT elec to CR)
- Verifies data received from BMT
- Displays statistical info for BMT data & error conditions

BMT Boom Motion Tracker
CR Control Room

Real Time Control Computer (RTCC)

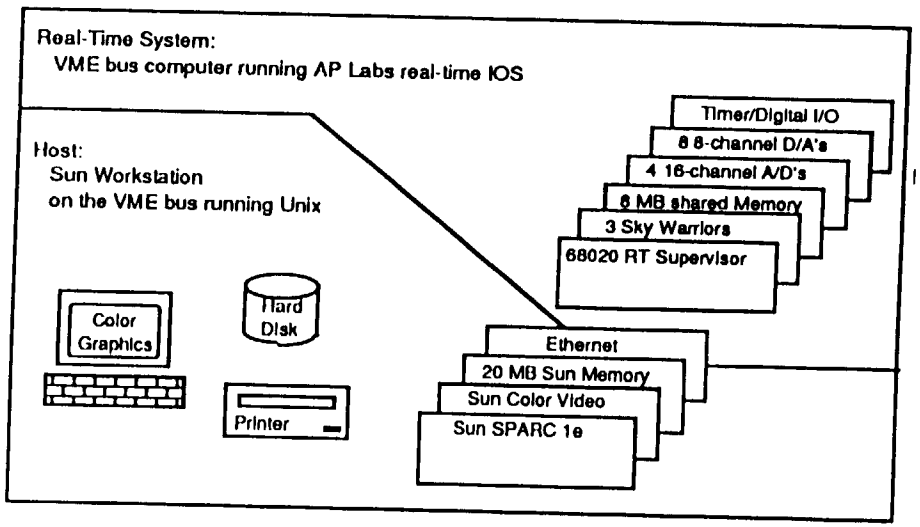


- 64 Inputs, 64 Outputs

  100th order Linear controller at 250 Hz

- Sun Host (on VMEbus running Unix)

  AP Labs Real-Time System (on VMEbus running IOS) with 3 Sky Warrior APs



APs Array Processors

LOGICON

Control Dynamics

RTCC Activities

- Extensive software modifications (CDy)

  Expand software to command actuators in Lab Frame in EUs (Engineering Units)

  Incorporate scale factor definition file

  Modify software to plot selected sensors & actuators in EUs

- Define scale factors, transformation matrices, biases for sensors & actuators

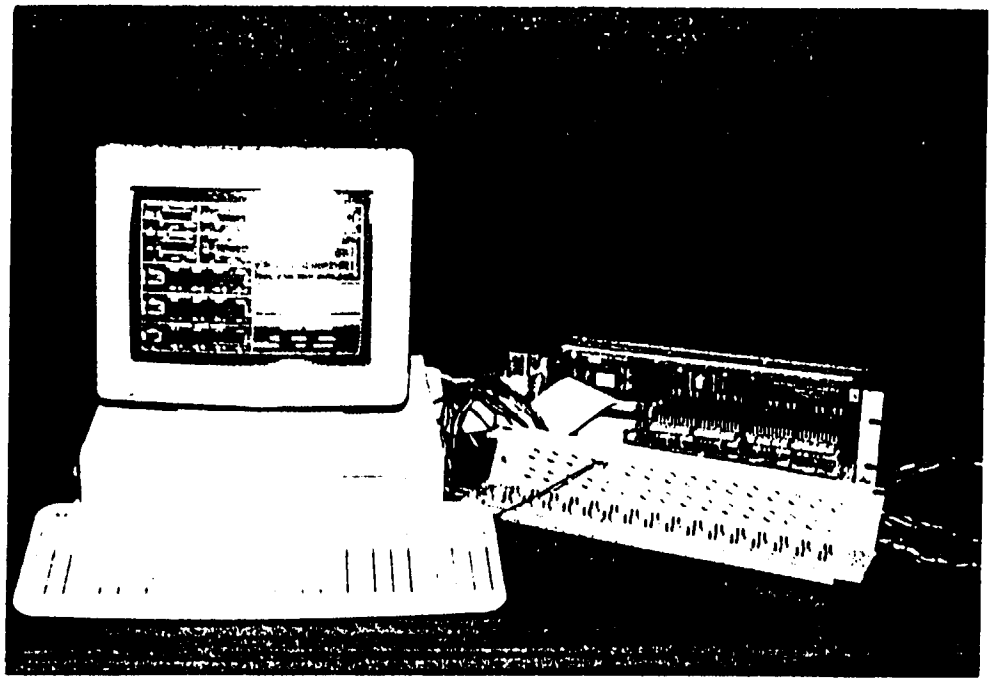
- Develop software for post-processing data (CDy)

  Imperative to have good post-pro SW (Software) due to LARGE amounts of data (1 minute run produces 3.8 MB of data)

C Program:	RNR	Strips individual variables from RTCC O/P file
M-file:	GETNAMR	Defines variables in Matlab from RTCC O/P file
C Program:	AVGDAT	Averages time steps of variables (compress data)
M-file:	WRITEM	Prepares RTCC input files for ABCD matrices
M-file:	EUBIGP	Plots test data (selected sensors/actuators) in Matlab

- Backup RTCC SW & Backup all test data files

Safety Monitor System Description



- Dedicated PC-based data acquisition system
- Monitors and graphically displays GTF safety-critical signals:

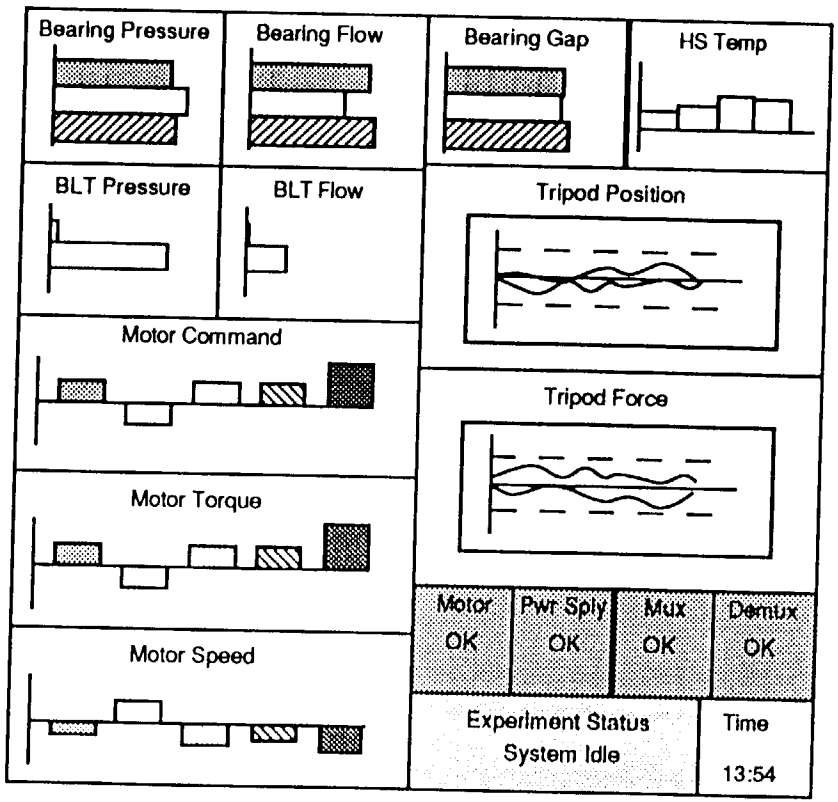
  Tripod position, air bearing and thruster pressures and flows, facility temperature and humidity, AMED motor and demux fault indicators, AMED heat sink temps.
- Checks safety limits; can signal RT computer for system shutdown.
- Currently monitors 46 signals (64 is max) at 50 Hz. Graphics updated at 5 Hz.

- Components:

  Gateway 386 SX computer,
  National Instruments 8 differential channel A/D
  National Instruments 32 differential channel MUX (2)
  National Instruments DOS labdriver software (C-based)
  Quinn-Curtis real-time graphics software (C-based)

SMS Activities

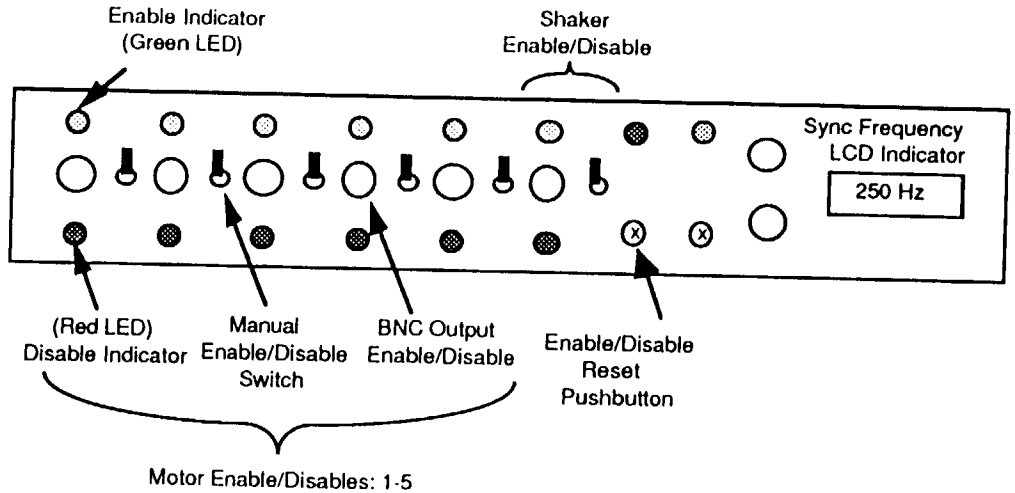
- Added scale factors to display in EUs (Engineering Units)
- Added DS Force variables & display
- Expanded cutoff capability: Motor Fault, Motor Speed, Bearing Gap, DS Force



DS Disturbance System
EUs Engineering Units

Auto-Cutoff System

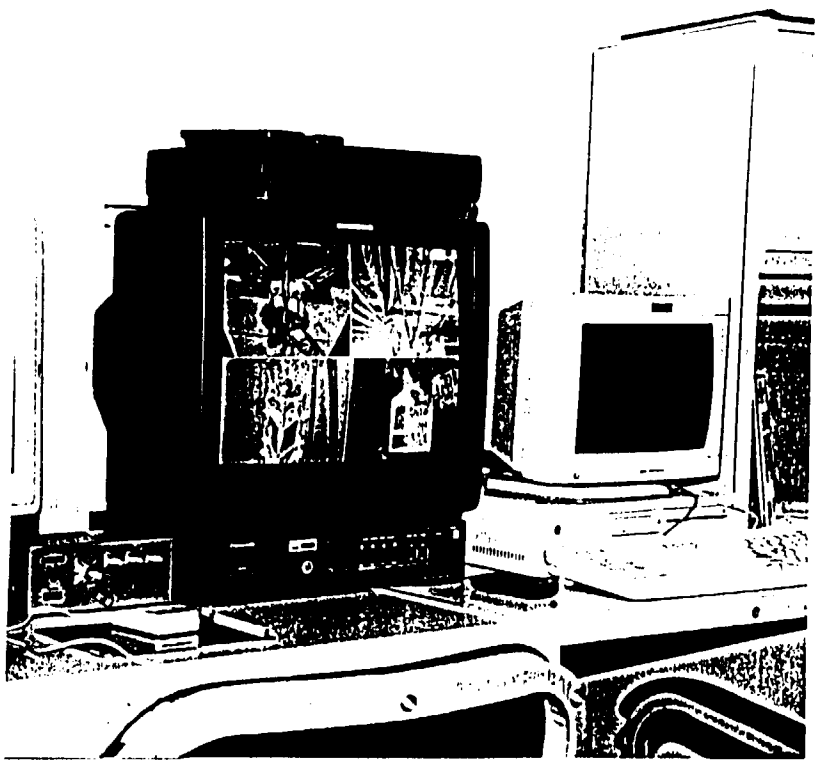
- Designed, Developed & Integrated by ED-73 and CDy (this year)
- Auto-Cutoff System disables Motors & Shakers in emergency situation
- Allows manual enable/disable of motors & shakers (from panel in CR)
- Interfaced with SMS which notifies of emergency conditions



CR Control Room
SMS Safety Monitor System

LOGICON
Control Dynamics

Video Monitor System



- Concept, Design & Implementation by CDy (this year)
- Useful for Safety & Demonstrations
- Allows observation of 4 locations from CR

  Dist System, Mid-AMED, Boom, Tip Plate
- Components: TV Monitor, Quad-splitter, VCR, 1 Color Video Camera, 3 B/W Cameras
- DS Camera mounted on remote-control Pan/Tilt system
- DS Camera modified to allow remote zoom

AMED Angular Momentum Exchange Device
DS Disturbance System
CR Control Room

LOGICON

Control Dynamics

Computer System: Future Recommendations

Recommended Upgrades	Benefits
Incorporate Digital I/O Capability	Allow subset of BMT targets to be used as a control sensor
Investigate adding parallel processing capability	Allow dynamic update of lab-to-body transformation matrices
Change operation procedure to shut-down RTCC	Eliminate need for operator to use root

BMT Boom Motion Tracker
I/O Input/Output
RTCC Real Time Control Computer

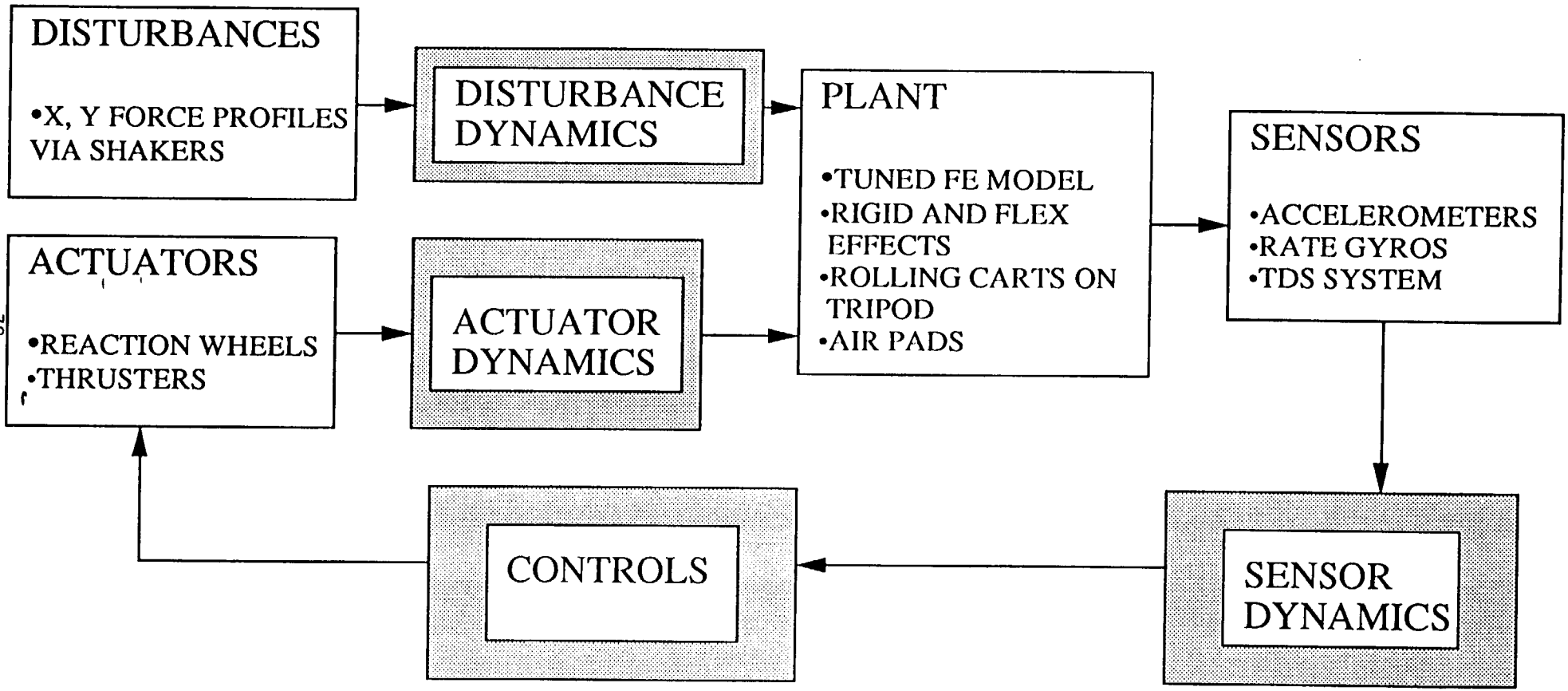
3.6 CSI Model/Simulation

This section discusses the Treetops simulation developed to use in modeling the CSI/CASES facility and provides results generated using a preliminary finite element model. The remainder of the section discusses the development and tuning of the actual NASTRAN finite element model. Results (frequencies and mass properties) are provided from the final model along with modeshape comparisons with the actual modal test results. Recommended upgrades and additions to the model and simulation are listed at the end of the section.

CSI GTF Simulation

- Based upon Treetops Software, Version 9
- Flexible body model, MSC NASTRAN Version 65C2
  Includes: Boom, MPESS, Tripod, and Tip plate
- Full Sensor/Actuator Set
- Documented in Report

CSI GTF Simulation, Continued



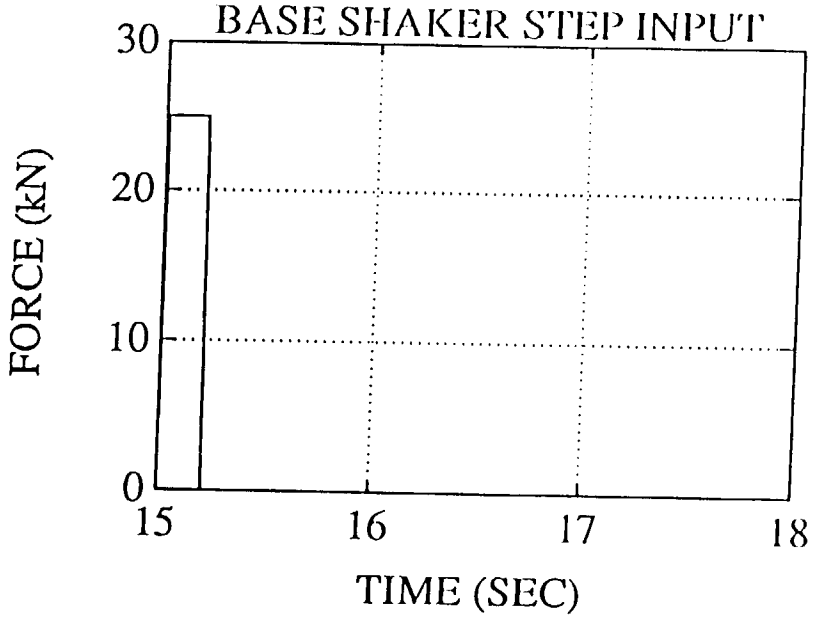
CSI GTF Simulation, Continued

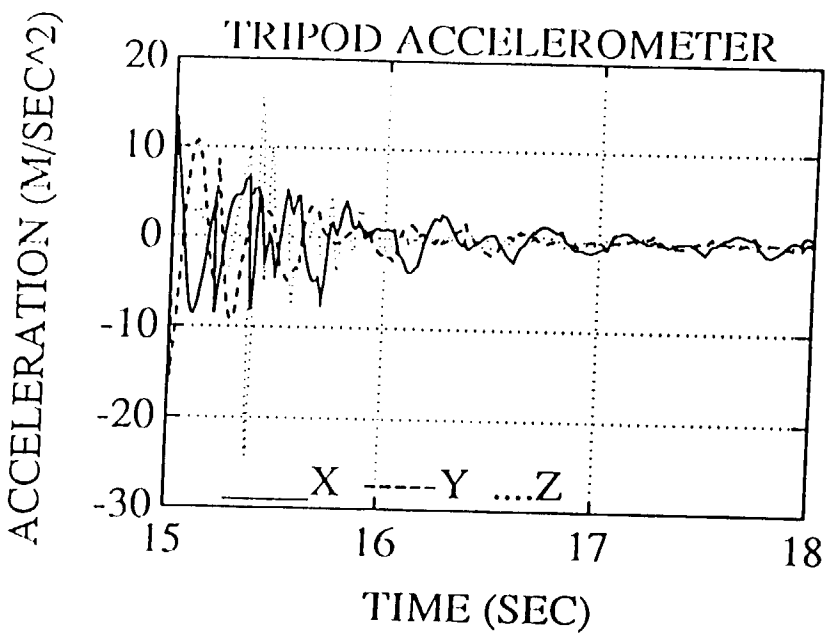
- Flexible Nastran Body
  - 2 Rigid Body Shakers - Translated in XY Plane wrt Flexible Body
  - 3 Rigid Air Pad Bodies - Translate in Z wrt Flexible Body

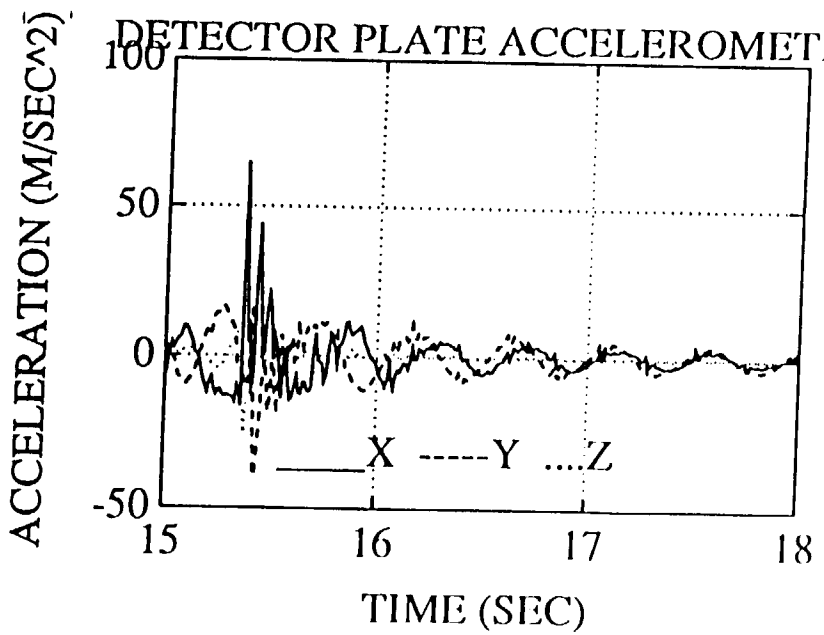
- Full Sensor and Actuator Set

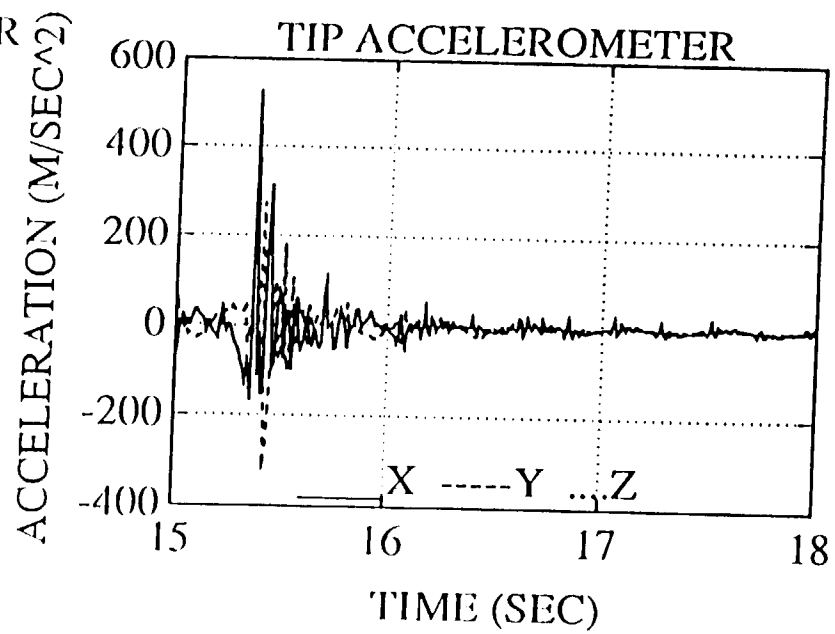
- Disturbances applied at Shakers and BLTs

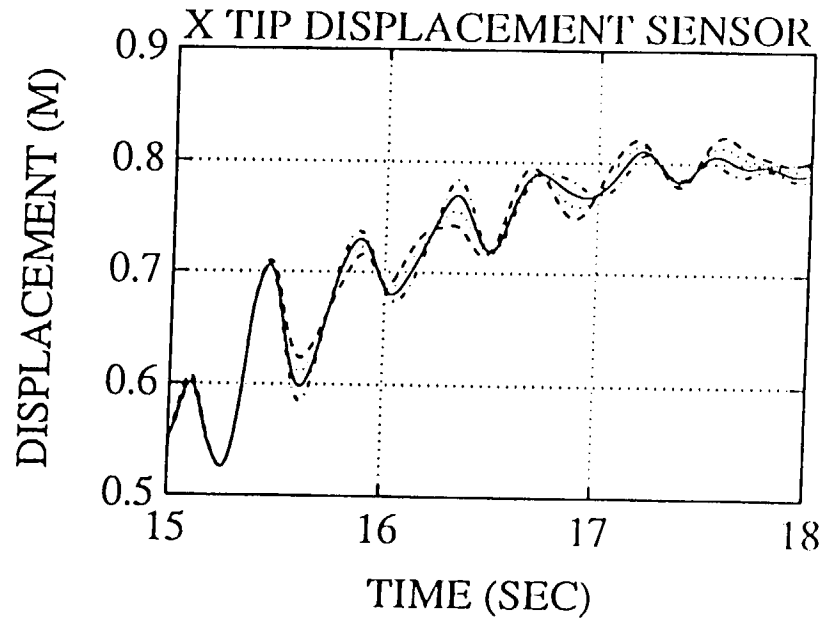
CSI GTF Simulation Results

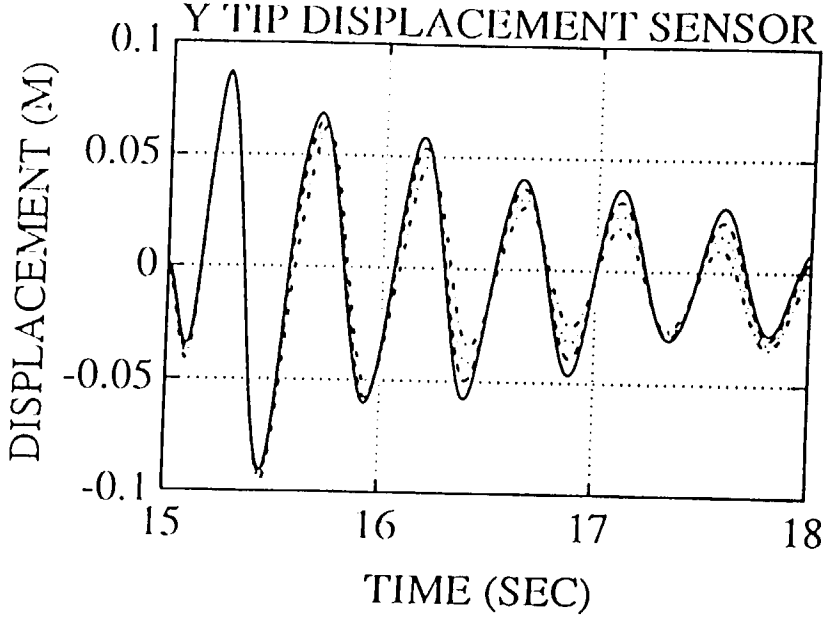

BASE SHAKER STEP INPUT
FORCE (kN)
30
20
10
0
15
16
17
18
TIME (SEC)

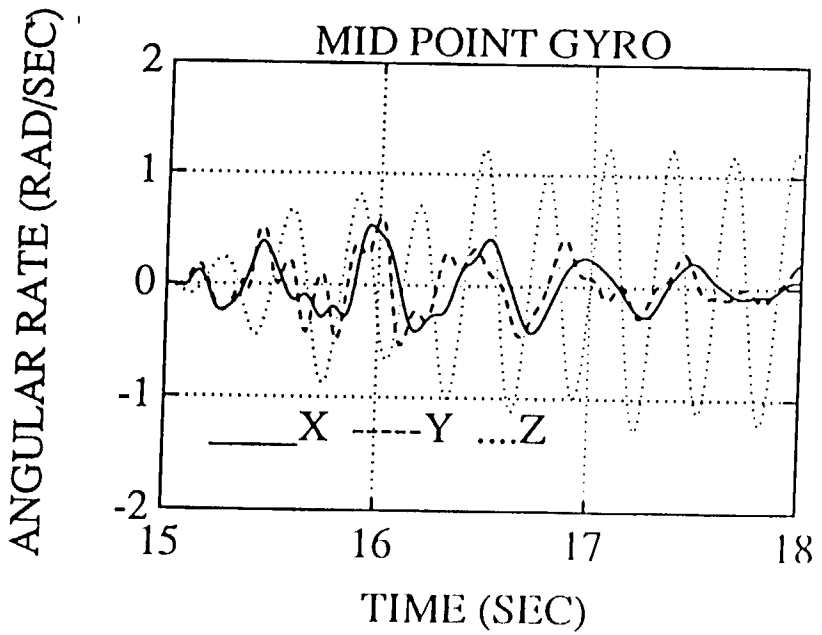

TRIPOD ACCELEROMETER
ACCELERATION (M/SEC^2)
20
10
0
-10
-20
-30
X -----Y ....Z
15
16
17
18
TIME (SEC)

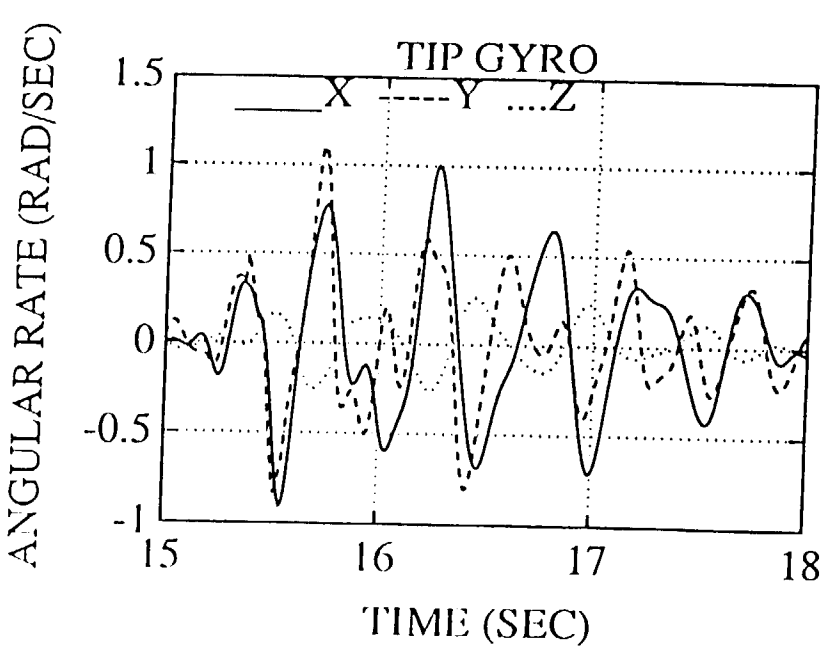

DETECTOR PLATE ACCELEROMETER
ACCELERATION (M/SEC^2)
100
50
0
-50
X -----Y ....Z
15
16
17
18
TIME (SEC)

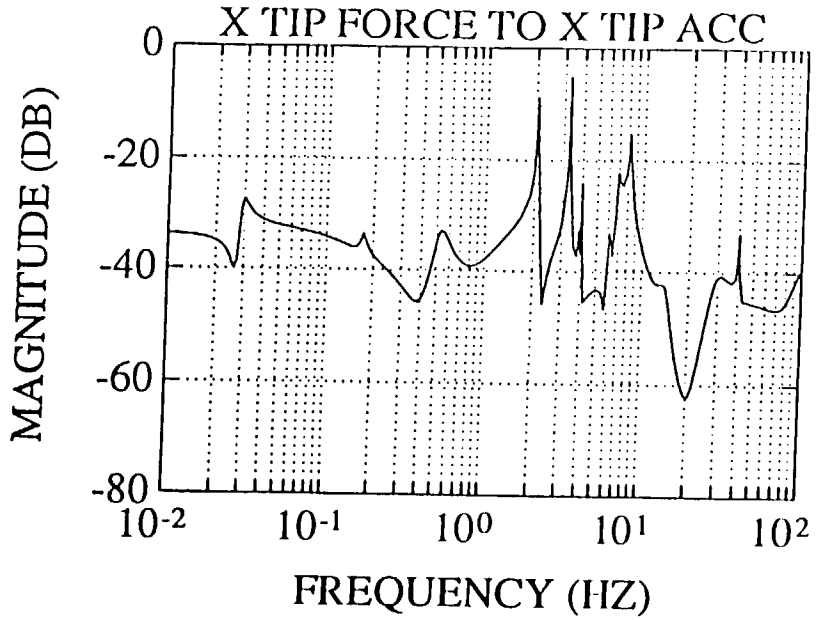

TIP ACCELEROMETER
ACCELERATION (M/SEC^2)
600
400
200
0
-200
-400
X -----Y ....Z
15
16
17
18
TIME (SEC)

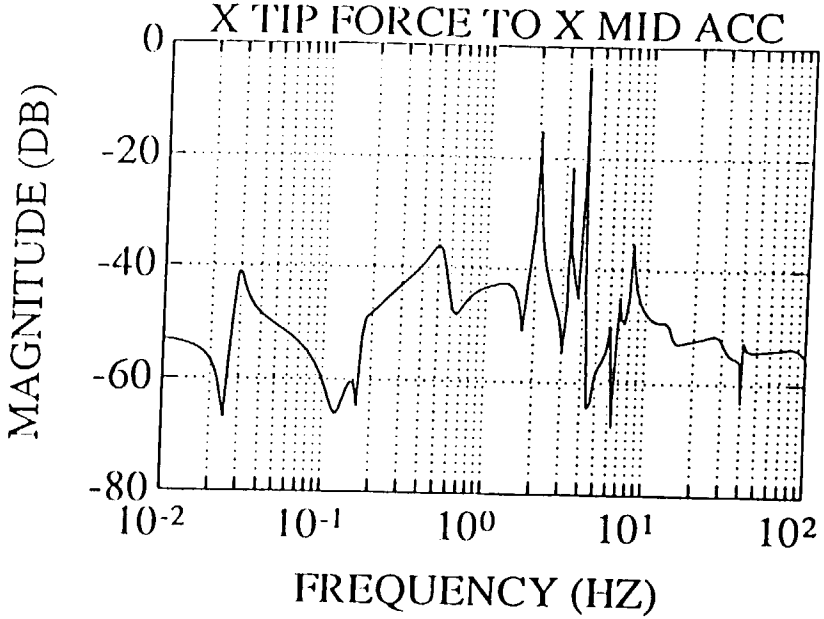

X TIP DISPLACEMENT SENSOR
DISPLACEMENT (M)
0.9
0.8
0.7
0.6
0.5
15
16
17
18
TIME (SEC)

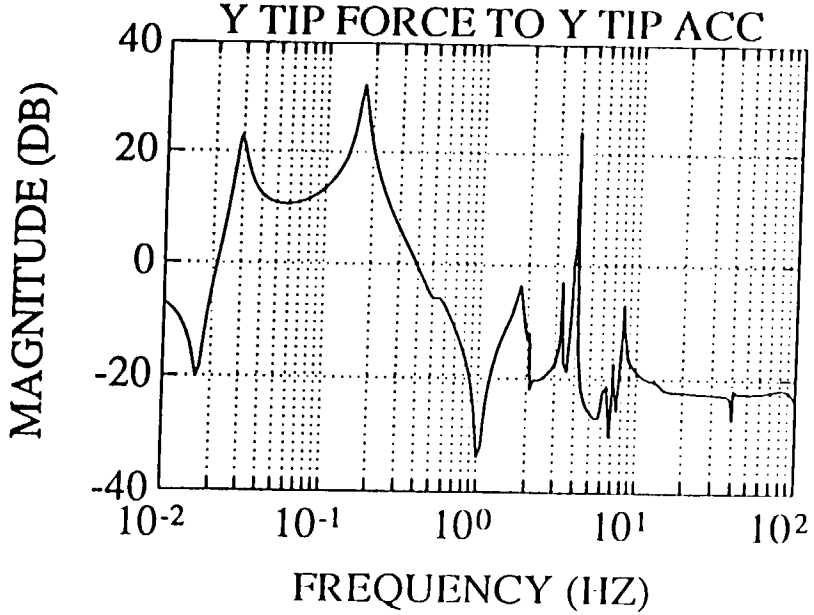

Y TIP DISPLACEMENT SENSOR
DISPLACEMENT (M)
0.1
0.05
0
-0.05
-0.1
15
16
17
18
TIME (SEC)

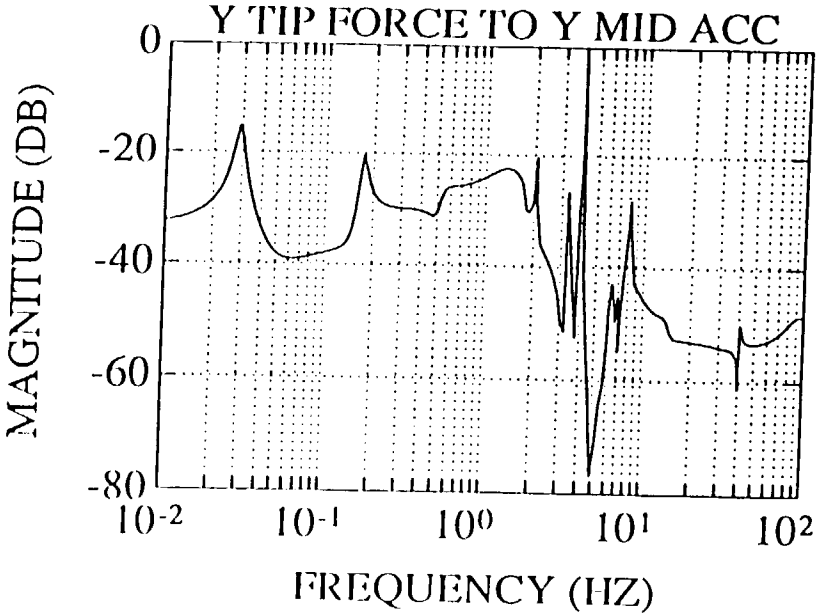

MID POINT GYRO
ANGULAR RATE (RAD/SEC)
2
1
0
-1
-2
X ----Y ....Z
15
16
17
18
TIME (SEC)

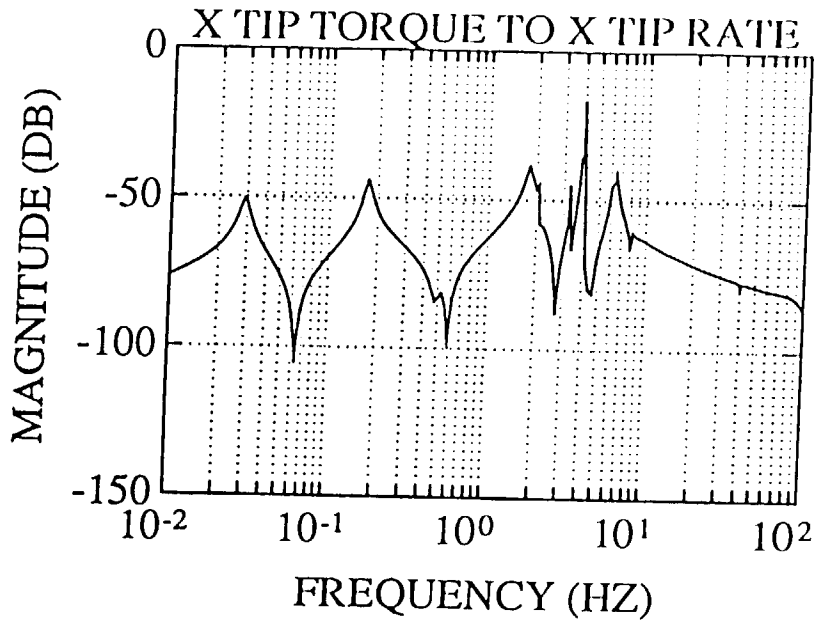

TIP GYRO
ANGULAR RATE (RAD/SEC)
1.5
1
0.5
0
-0.5
-1
X ----Y ....Z
15
16
17
18
TIME (SEC)

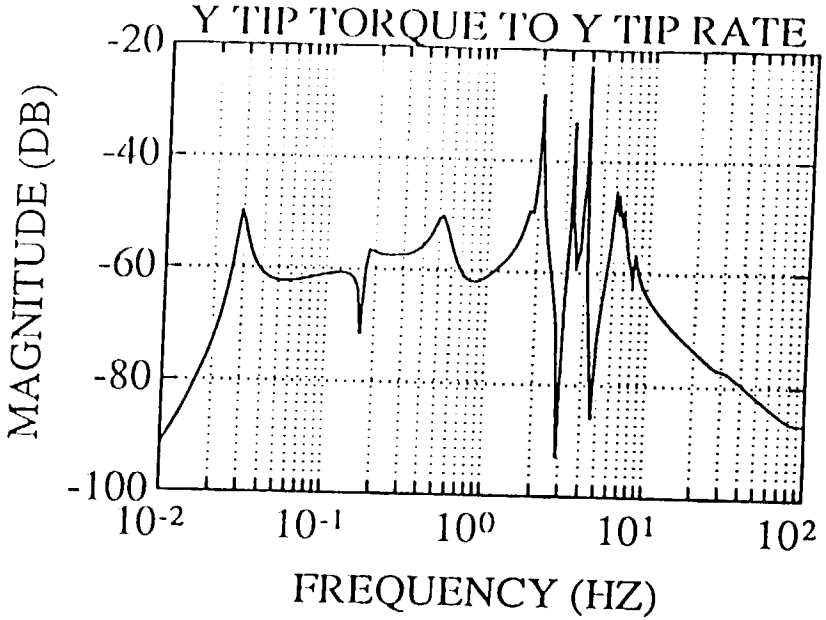

X TIP FORCE TO X TIP ACC
MAGNITUDE (DB)
0
-20
-40
-60
-80
10-2
10-1
100
101
102
FREQUENCY (HZ)

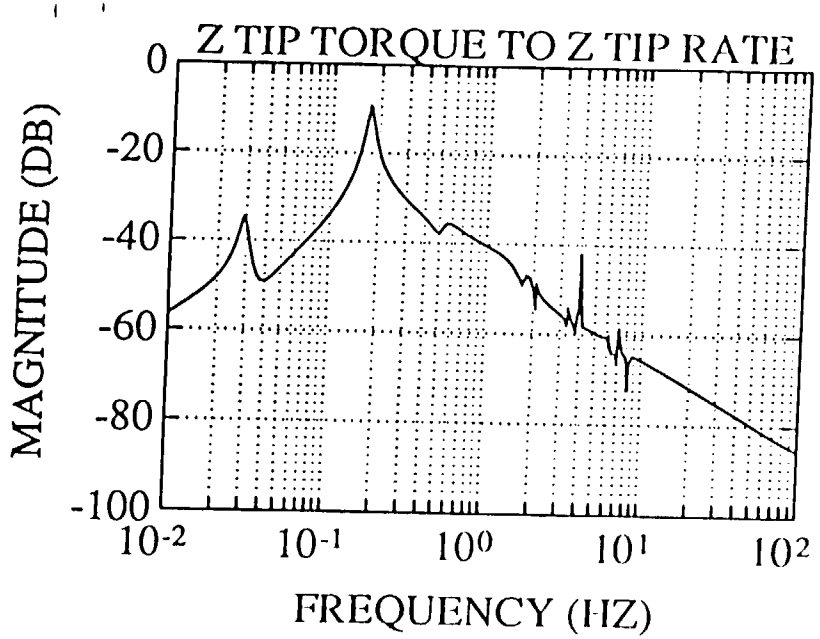

X TIP FORCE TO X MID ACC
MAGNITUDE (DB)
0
-20
-40
-60
-80
10-2
10-1
100
101
102
FREQUENCY (HZ)


Y TIP FORCE TO Y TIP ACC
MAGNITUDE (DB)
40
20
0
-20
-40
10-2
10-1
100
101
102
FREQUENCY (HZ)


Y TIP FORCE TO Y MID ACC
MAGNITUDE (DB)
0
-20
-40
-60
-80
10-2
10-1
100
101
102
FREQUENCY (HZ)


X TIP TORQUE TO X TIP RATE
MAGNITUDE (DB)
0
-50
-100
-150
10-2
10-1
100
101
102
FREQUENCY (HZ)


Y TIP TORQUE TO Y TIP RATE
MAGNITUDE (DB)
-20
-40
-60
-80
-100
10-2
10-1
100
101
102
FREQUENCY (HZ)


Z TIP TORQUE TO Z TIP RATE
MAGNITUDE (DB)
0
-20
-40
-60
-80
-100
10-2
10-1
100
101
102
FREQUENCY (HZ)

CSI GTF Simulation, Continued

- Good First Cut Simulation Tool
- Recommendations
  - Include Latest Finite Element Model Results
  - Include more than 20 Flexible Body Modes
  - Have Tip Plate be a separate Flexible Body
  - Measure LMS Rail Stiffness Characteristics
  - Compare Gravity Options between NASTRAN and Treetops Simulation

CSI GTF Finite Element Model

- Flexible Body Model includes:
  - Boom, MPESS, Tripod, and Tip Plate
- Incorporated Tip Extender Package
- Lumped Mass Components
  - LMS, AMEDs, Cabling and Hose, etc.
- Metric Model
- Added Grids at all Sensor/Actuator Locations
- 2 Stage Solution
  - Nonlinear Static to incorporate Gravity Effects
  - Eigensolution

CSI GTF Finite Element Model, Continued

- Convergence Problems
  - Static Nonlinear Solution - Gravity Effects Undergoes Large Angular Motion

- Remedies Tried
  - Adjusting Bungee Stiffness Values
  - Modifying Constraints
  - Adjusting Number of Load Steps and Iterations/Step
  - Re-oriented Gravity Vector to go through Boom Tip
  - Vertical Weight Loading of Boom, with Light Tip Plate

CSI GTF Finite Element Model, Continued

Resulting Configuration

- Static Solution 66
  - Base is Constrained
  - Bungee Springs have X, Y, and Z Values, Previously just Z
  - Tip Plate made essentially Massless with very light Bungee Springs
  - Concentrated Mass and Inertia Values were added to Tip Extender

- Eigensolution 63
  - Base is Freed-up in X and Y
  - Bungee Springs have X, Y, and Z Values, Previously just Z
  - Tip Plate Mass Restored
  - Bungee Stiffness Restored
  - Concentrated Mass and Inertias Removed from Tip Extender
  - ASET with 425 Degrees of Freedom

CSI GTF Finite Element Model, Continued

Model Facts:

- 777 Grid Points
- 244 Beam Elements
- 11 Springs
- 555 Quad Plate Elements
- 131 Tria Plate Elements
- Mass = 2235.766 Kg
- CG = (-0.6593183, -9.725136E-5, -1.4865) meters
- Inertia about CG

$$\begin{bmatrix} 9.639672E+4 & -7.02168E-2 & 1.383586E+3 \\ -7.02168E-2 & 9.630034E+4 & -8.218950E-2 \\ 1.383586E+3 & -8.218950E-2 & 2.048537E+3 \end{bmatrix}$$

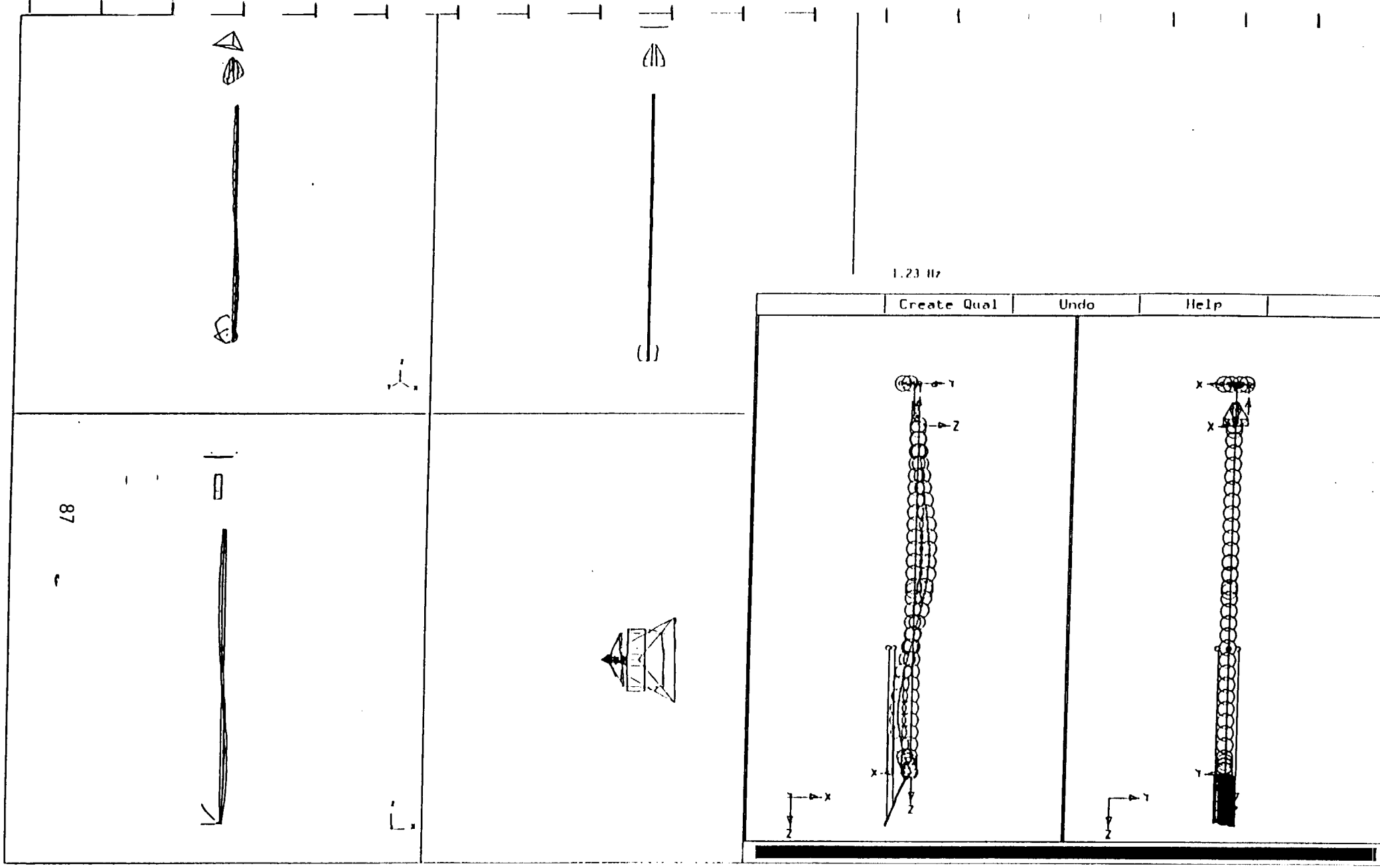
CSI GTF Finite Element Model, Continued
Analytical Results

Frequency (Hz)	Modeshape Description	Frequency (Hz)	Modeshape Description
1.E-5, 1.E-5	rigid body motion	10.18	torsion
0.08	Y 1st bending	10.42	tip plate bending
0.09	X 1st bending	11.00	X bending
0.16	torsion	11.32	Y bending w/ tip plate
0.56	X 2nd bending	14.18	torsion
0.58	Y 2nd bending	14.24	torsion
1.23	X 3rd bending w/ tip plate	14.99	tip plate bending
1.82	Y 3rd bending w/ tip plate	15.43	X bending
1.98	X bending w/ tip plate	15.47	Y bending w/ tip plate
2.73	Y 4th bending w/ tip plate	17.01	torsion
3.07	Y bending w/ tip plate, mpess	17.50	tip plate w/ Y bending
3.28	X 4th bending w/ tip plate	19.09	X bending w/ tip plate
3.38	torsion	19.38	Y bending w/ tip plate
3.61	Y bending w/ tip plate	21.10	torsion w/ Y bending
3.71	X bending w/ mpess	21.21	tip plate bending
5.39	X bending w/ tip plate	21.50	torsion
5.63	Y bending w/ tip plate	23.28	tip plate bending
6.70	X bending w/ mpess & tip plate	23.75	X bending
7.11	torsion	23.80	Y bending
8.22	tip plate w/ Y bending	23.99	torsion
8.35	X bending	24.74	mpess w/ Y bending
8.97	tip plate w/ bending X&Y	25.63	tip plate bending
9.09	tip plate	28.40	torsion
9.91	tip plate bending	29.50	mpess w/ X bending

CSI GTF Finite Element Model, Continued
Frequency Comparison

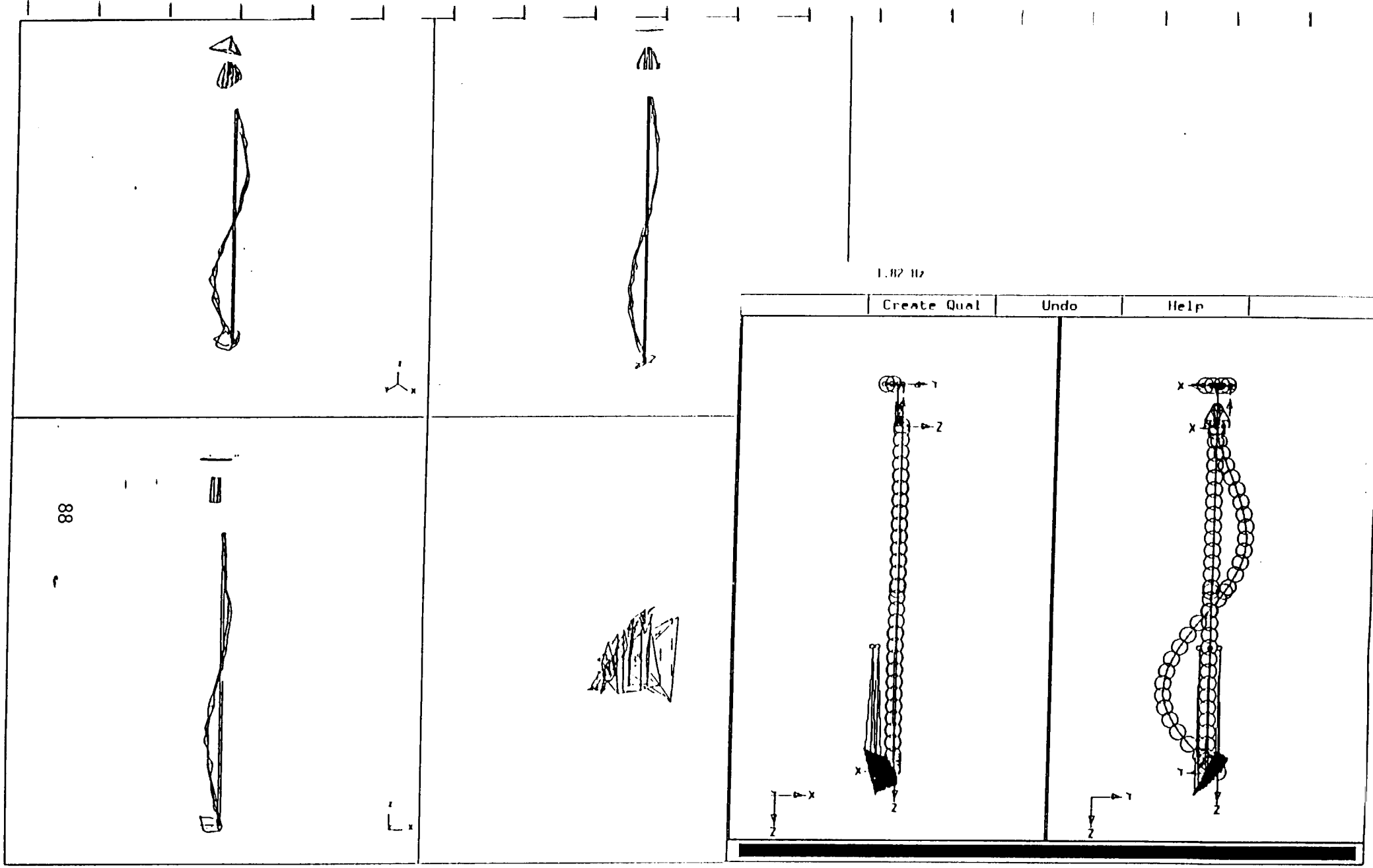
Experimental Frequency (Hz)	Analytical Frequency (Hz)
0.112	0.08
0.120	0.09
0.210	0.16
0.520	0.56
0.530	0.58
1.391	1.23
1.868	1.82
2.802	2.73
2.995	3.28
3.133	3.38
4.215	3.71
4.598	3.61
4.974	5.63
6.027	6.70
6.565	8.35
6.703	7.11
8.182	8.22
9.864	9.91
10.864	10.18
12.312	11.00

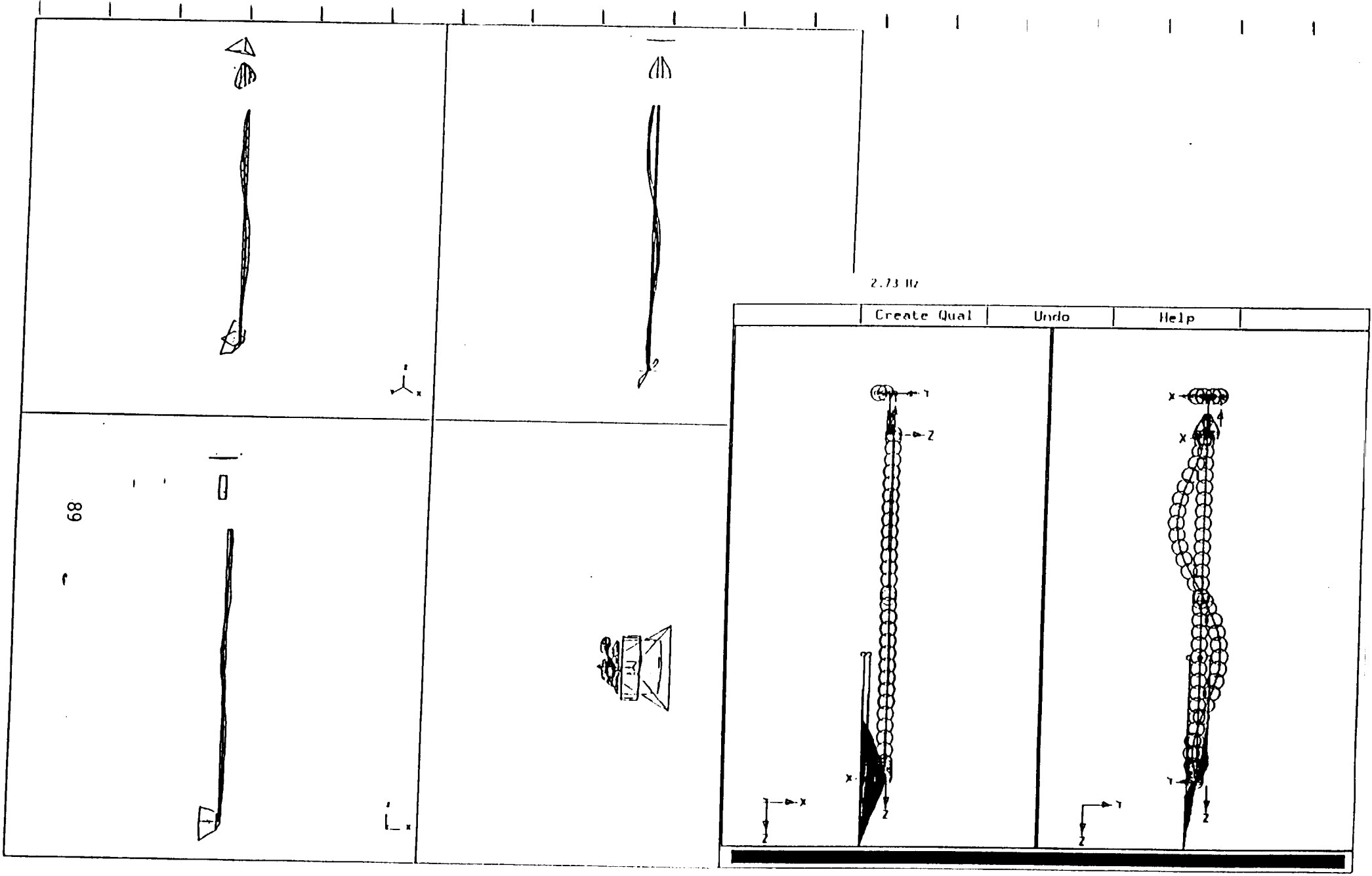
CSI GTF Finite Element Model
Modeshape Comparisons

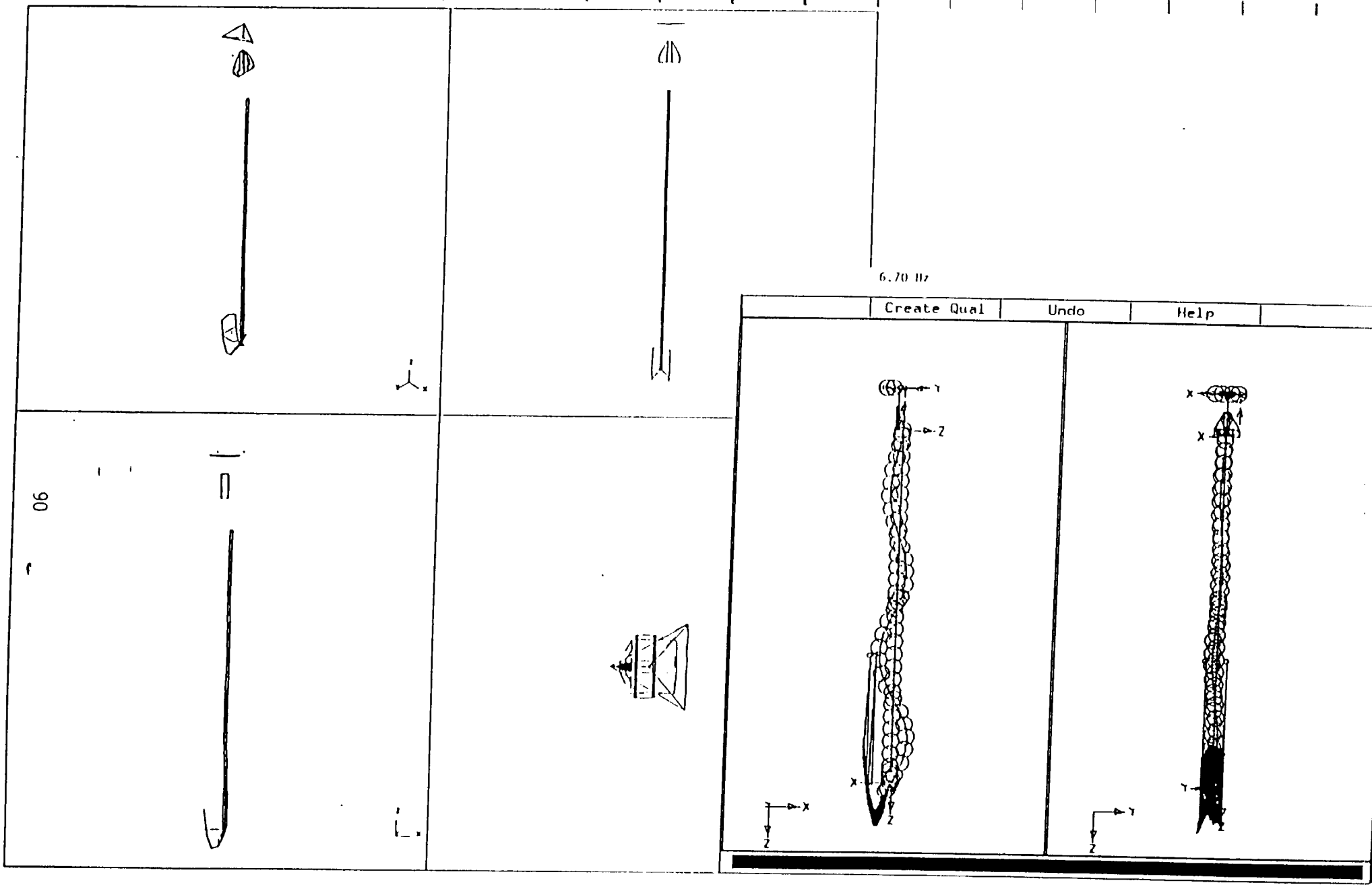


LOGICON

Control Dynamics

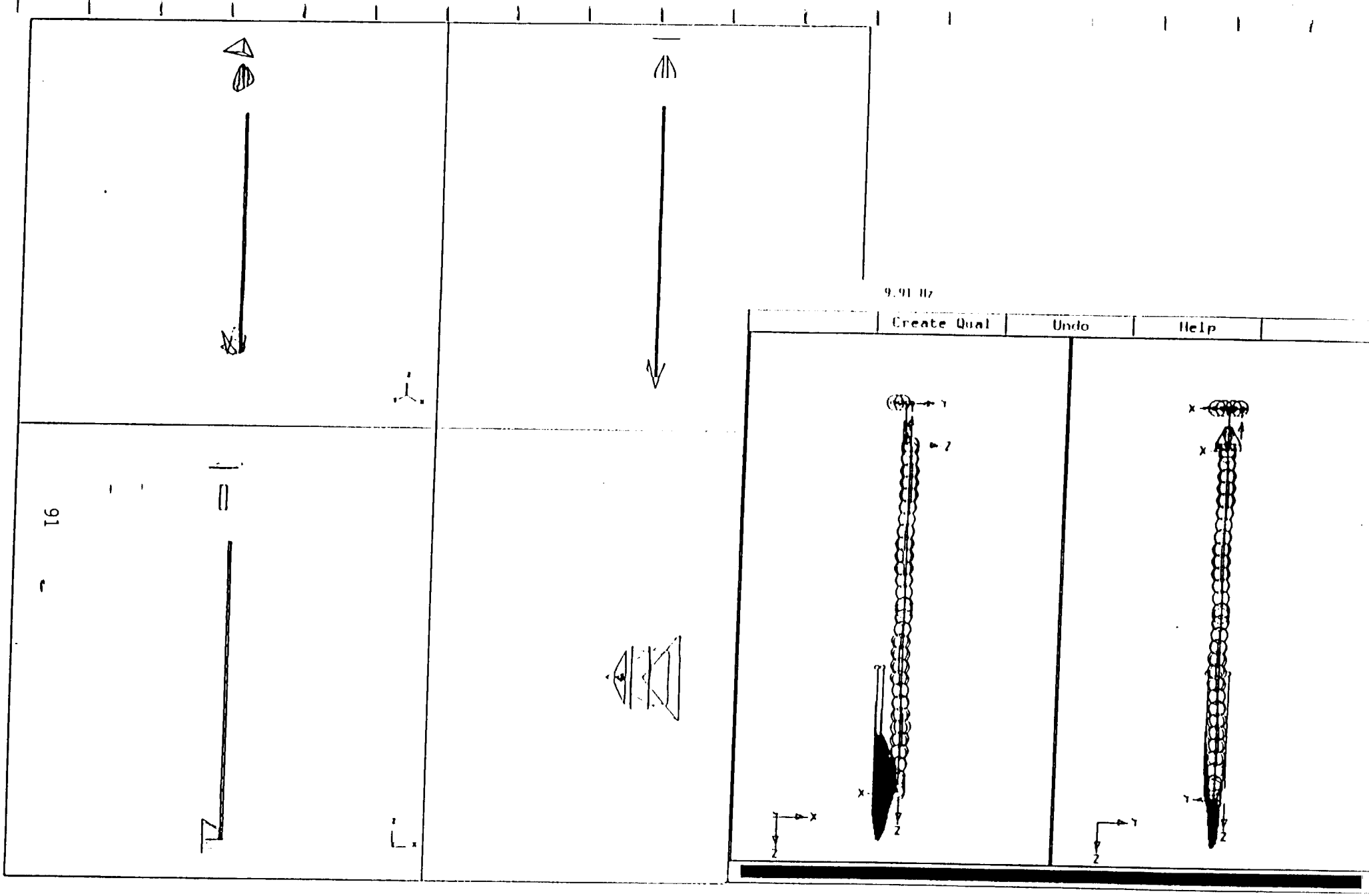

1.82 Hz
Create Qual
Undo
Help


2.73 Hz
Create Qual
Undo
Help



LOGICON

Control Dynamics



LOGICON

Control Dynamics

CSI GTF Finite Element Model, Continued

- Documented in Report
- Recommendations
  - Incorporate every Boom Bay as a Beam Element
  - Add BMT and TDS Systems
  - Update AMED Packages

Closing Remarks

- Work in Systematic Manner
  - Model and Test Components
    (MPESS, Tip Plate, etc.)
  - Combine Components Mathematically and Physically
    Test and Tune
    (CSI GTF)

- Perform Modal Tests on Operational Configuration
  Lesson Learned from ACES

Model/Simulation: Future Recommendations

Recommended Upgrades	Benefits
Incorporate latest tuned FE model into new simulation	Higher fidelity model
Add damping values from modal test to simulation	More accurate damping values
Perform wider bandwidth system ID tests (Transfer Functions)	Better identify very low modes & also higher modes
Perform further comparison of analytical/experimental TFs	Allow further tuning of model/sim
Incorporate better model of DS characteristics from further DS testing	Better model/sim of shaker springs, friction, air pad springs, shaft bending, etc..
Perform modal test on present configuration	Configuration today slightly different from 1/92 configuration
Model each bay as beam element	Allow addition of BMT as sensor

BMT Boom Motion Tracker FE Finite Element

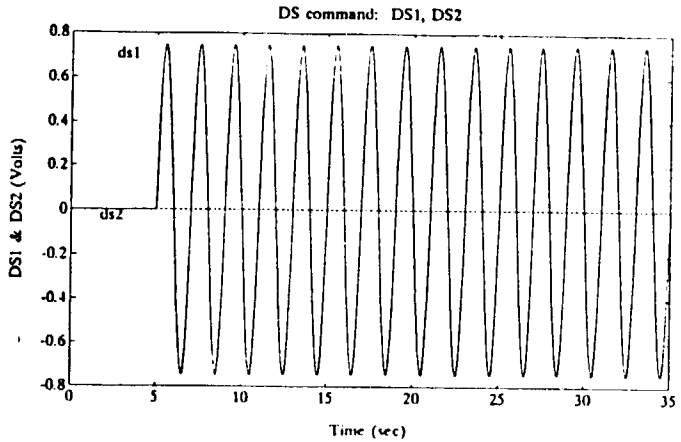
4.0 CSI/CASES Testing

This last section discusses the testing performed on several of the components to verify their capabilities. The results from these tests are provided. The systems tested include the disturbance system, the thrusters, the AMEDs, and system closed loop testing. Recommendations are included for each system.

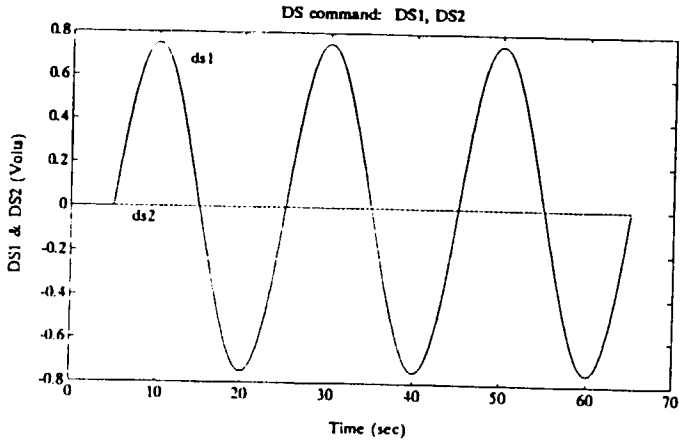
DS: Preliminary Verification Testing (Volts)

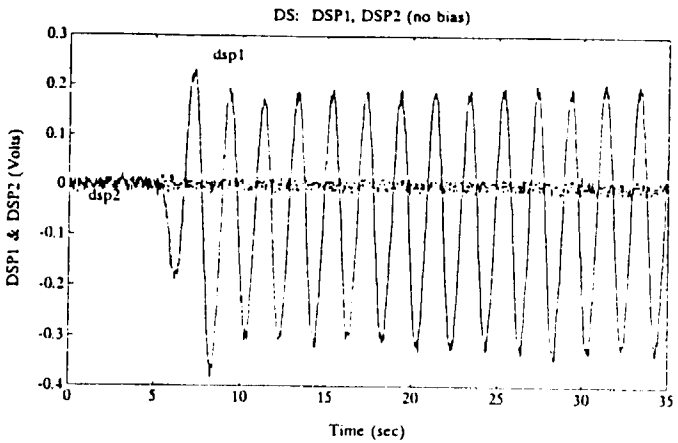
- Preliminary testing indicated significant non-linearities at low frequencies

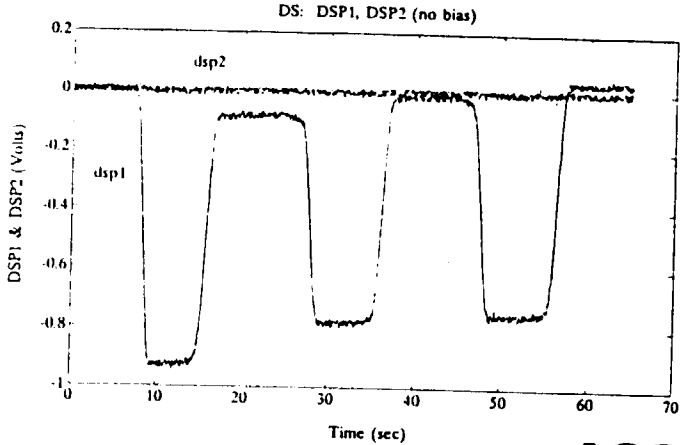
Pctest03: Shaker 1 Sine (0.5 Hz)



Pctest04: Shaker 1 Sine (0.05 Hz)







LOGICON

Control Dynamics

Disturbance System Testing

- Testing performed by CDy
- Last Year: DS Manual push, observe Position, Pressure (Volts)
- This Year: DS Shaker Excitation from RTCC; Observe all DS sensors in EUs
- **Functionality Tests:** Compare expected pressure, flow, gap of air bearing system

Results: Given Load = 5500 lbs & 190 psi

	Prediction	Actual
Air Gap	0.0027"	0.0020 - 0.0024"
Flow	2.3 ACFM	3.3 - 4.3 ACFM

Pressure drop of 5% between air panel and air pads

As expected, air pad 2 has a higher variance in gap (less constrained in Z)

- Further investigation of flow:
  - recalibrate flowmeters with present electronics & range settings
  - examine flowmeter linearity over this region
  - investigate if flow straighteners might help

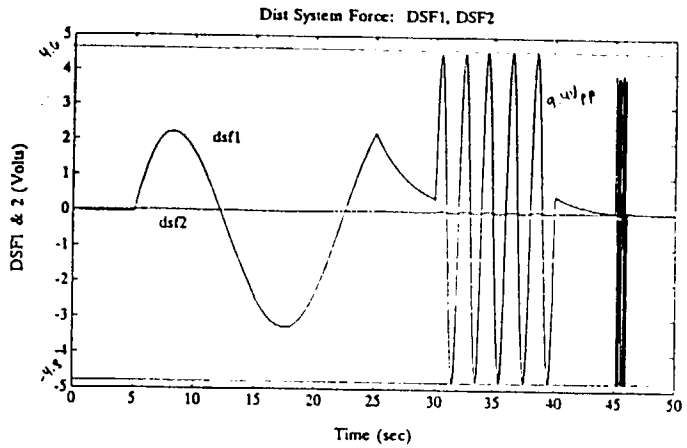
DS: Scale Factor Calculation

- Scale Factor Testing: Determine rough scale factor for shaker force command Pctest26 & Pctest27

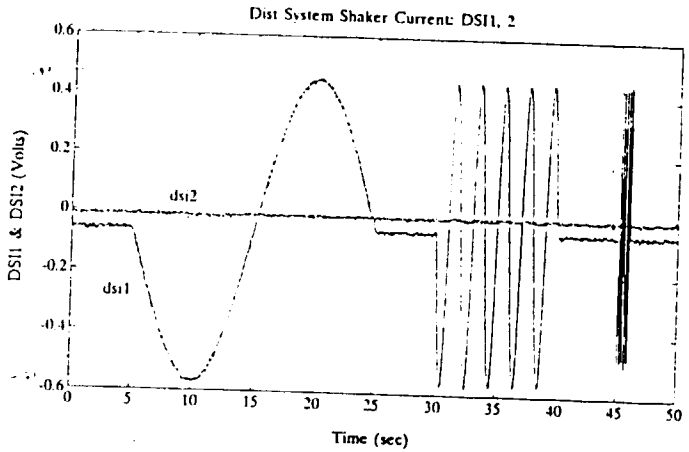
- Test Setup: Air off, Force command (3 sine frequencies)
  Measure actual force via calibrated force transducer (0.1031 V/lbf)
  Double check via shaker current scale factor (0.010 V/lbf)

Pctest26: Shaker 1 Sine (0.05, 0.5, 5 Hz)

Force Transducer



Shaker Current



- Scale Factor: Command = 2 Vpp Actual = 9.44 Vpp = 91.2 lbf Current = 104 lbf
  SF = 46 lbf/Cmd Volt (Force Transducer)
  SF = 52 lbf/Cmd Volt (Current)

LOGICON
Control Dynamics

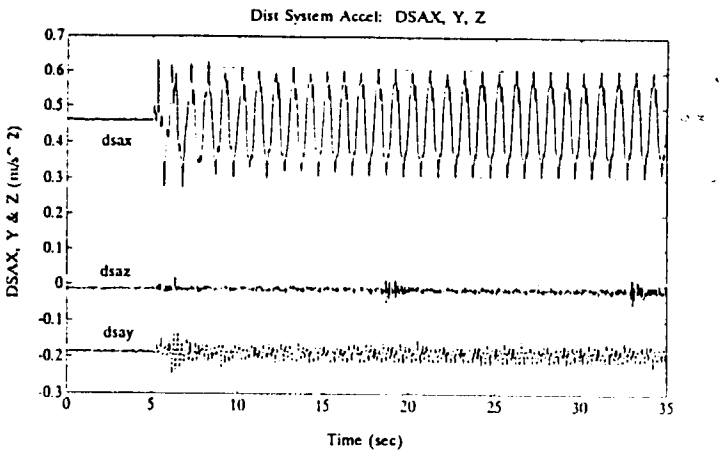
DS Testing: Sign, Phase, Magnitude Relations (EUs)

- Given Force sine wave: Freq=1 Hz, M =5500 lbs, Fpp = 650 N

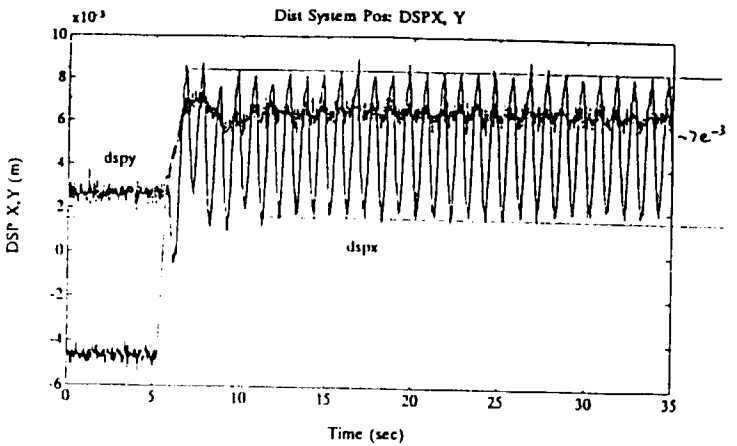
  Analytical Prediction: App = 0.26 m/s^2 Xpp = 6.6 e-3 m
  Experimental Results: App = 0.30 m/s^2 Xpp = 7 e -3 m

- Testing confirms DS & DSF are in phase, DS & DSA are in phase, DS & DSP are out of phase
- Testing shows DS command = 300 N results in DSF = 325 N (Fairly close)

Pctest52: DS Acceleration



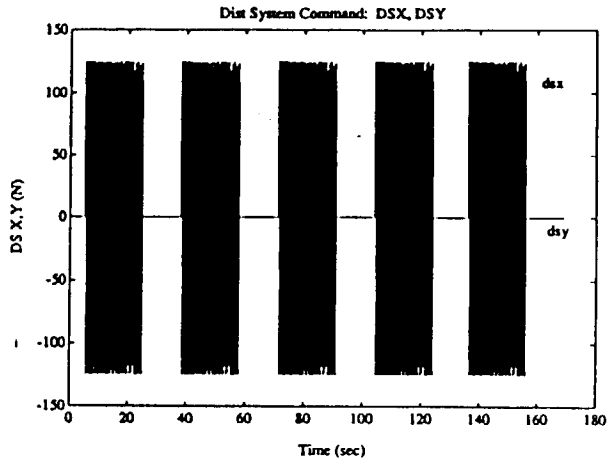
PCtest52: DS Position



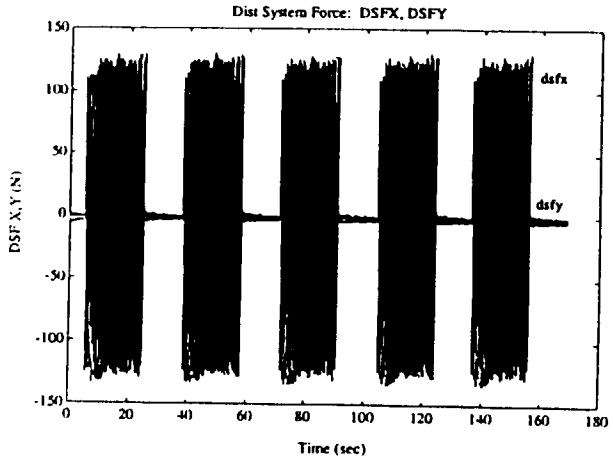
DS Testing: Transfer Functions (EUs)

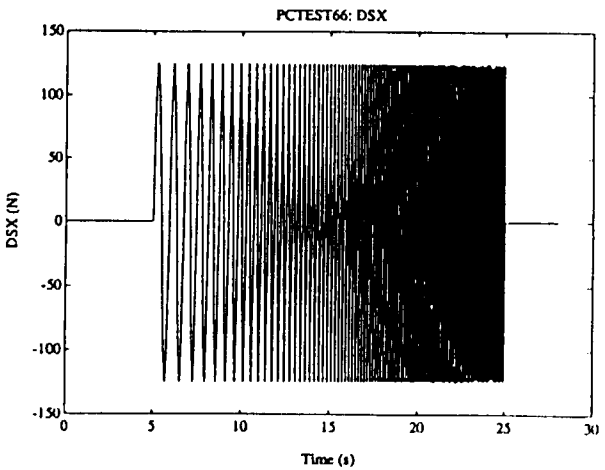
- Test: Five Log Sine Sweeps from 1 - 20 Hz in 20 sec followed by 13 sec of zero command

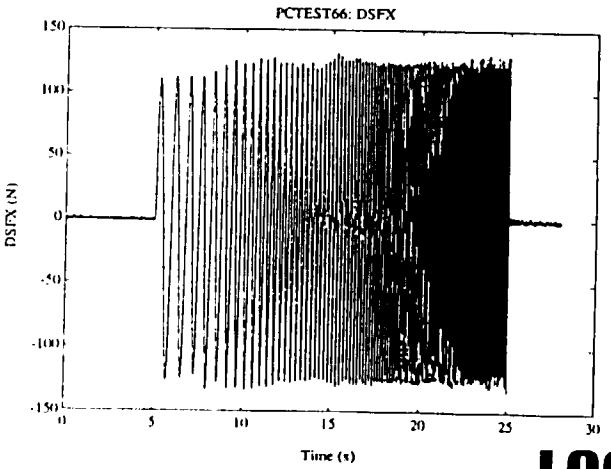
Pctest66: DS Command



Pctest66: DS Force







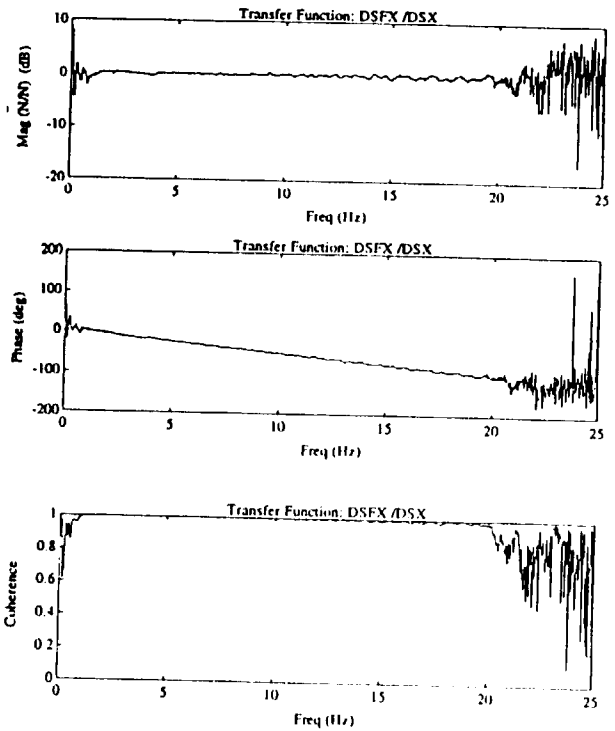
LOGICON

Control Dynamics

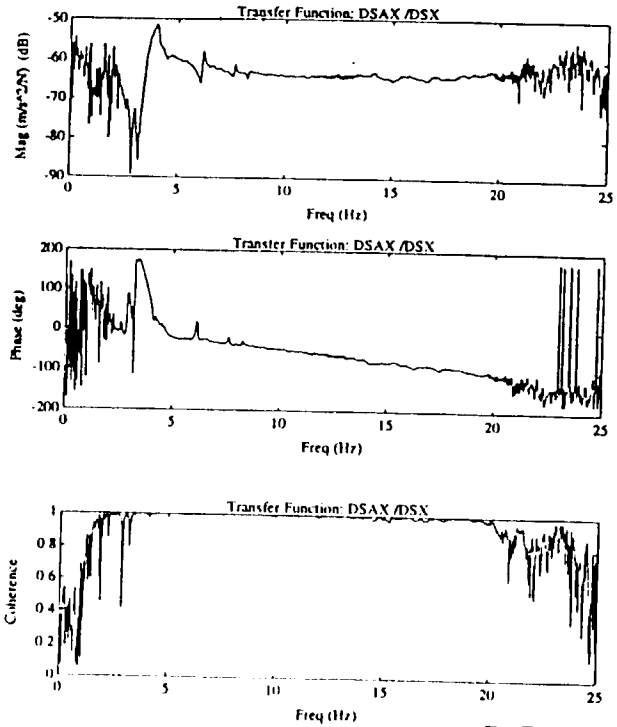
DS Testing: Transfer Functions (EUs)

- Test: Five Log Sine Sweeps from 1 - 20 Hz in 20 sec followed by 13 sec of zero command
- DSF/DS shows: force follows the command thru 20 Hz (test range) (i.e. mag=0db)
  phase delay of 90 deg at 20 Hz (M/D, LPF, RTCC, S & A Dynamics)
- DSA/DS shows: accel = force/mass (but, can see system modes 4 & 6 Hz)

Pctest66: DS Force/DC Command



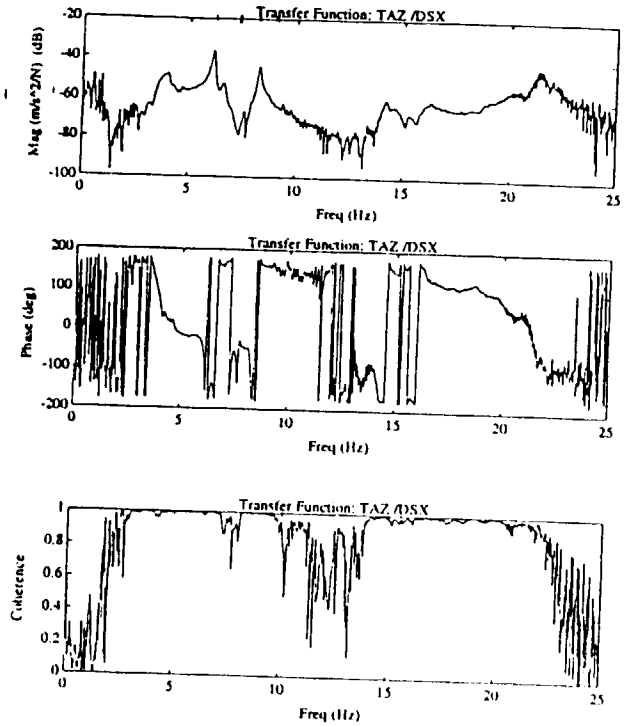
Pctest66: DS Accel/DS Command



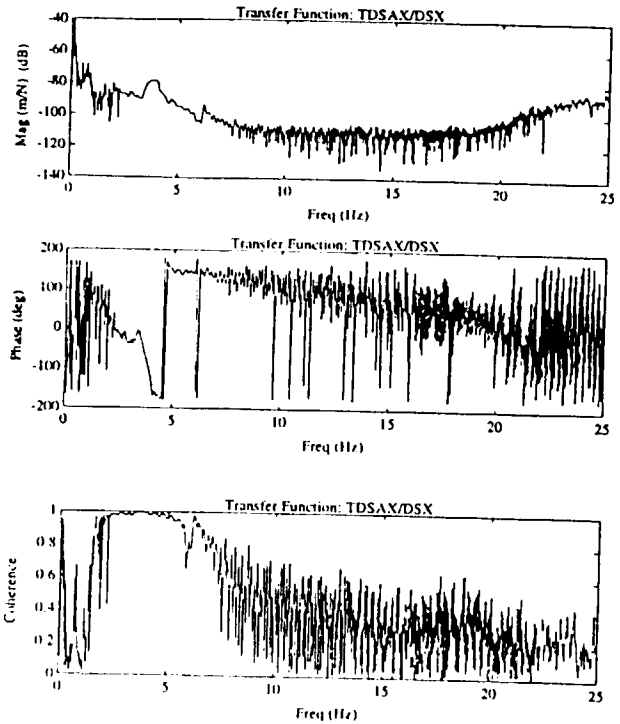
DS Testing: Transfer Functions (EUs)

- Test: Five Log Sine Sweeps from 1 - 20 Hz in 20 sec followed by 13 sec of zero command
- TAZ/DSX: Good deal of system dynamics in Z: 4.2 5th B-X, 6.0 & 8.2 Tip plate modes
  Also see some higher modes 15 & 22 Hz
- TDSAX/DSX: Basically see pend X mode (0.12 Hz) (Need lower freq sys ID test)

Pctest66: TAZ/DSX



Pctest66: TDSAX/DSX



LOGICON

Control Dynamics

Disturbance System: Future Recommendations

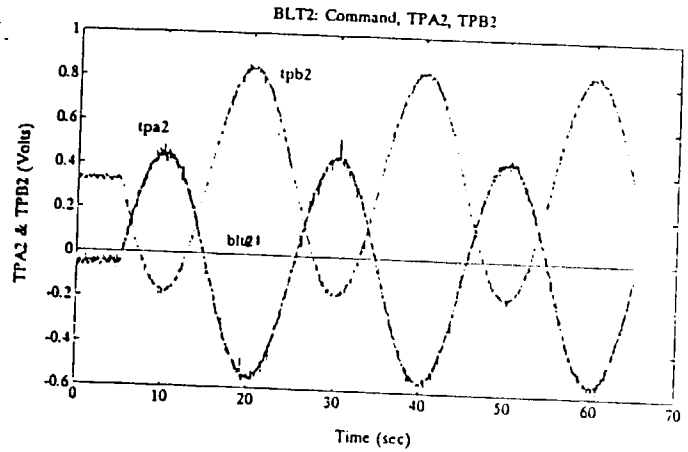
Recommended Upgrades	Benefits
Strengthen stinger/force transducer mechanical interface	Extend allowable force magnitude capability
Further testing & characterization of DS	Better understanding of lower frequency non-linearities, friction/stiction, mechanical spring
Further testing of scale factor of DS	More accurate DS command scale factor
Additional shaft support structure (from tower leg to bearing shafts near LMS)	Constrain torsional motion
Investigate adding servo system to DS	Better force or position following capability
Add LMS baffles	Less debris will accumulate on shafts
Carefully measure mass of experiment	Know exact mass of experiment

DS Disturbance System
LMS Linear Motion System

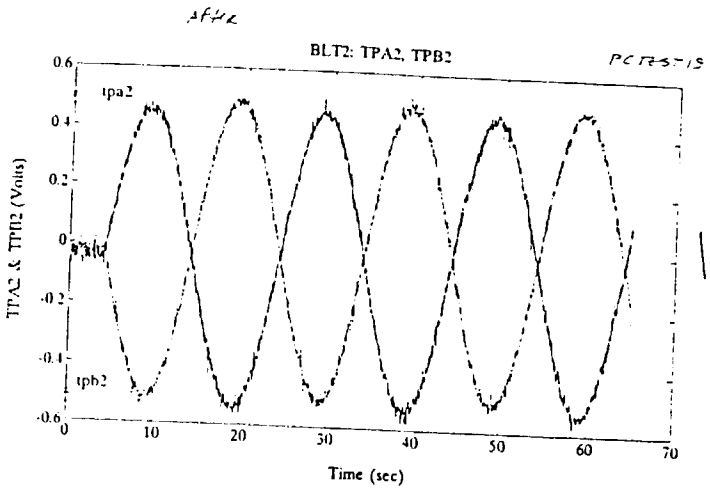
BLT: Preliminary Verification Testing (Volts)

- Preliminary testing indicated need to adjust BLT electronics bias adjustment

Pctest01: BLT 2 Sine (0.05 Hz)



Pctest19: BLT 2 Sine (0.05 Hz)



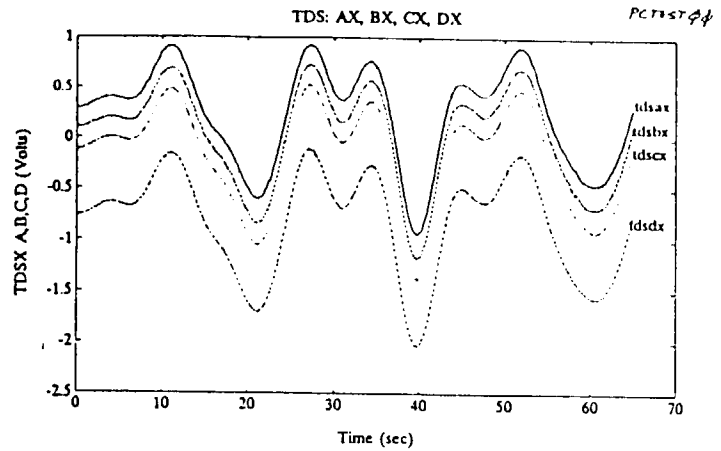
TPA = BLT Test Point A = Command/2

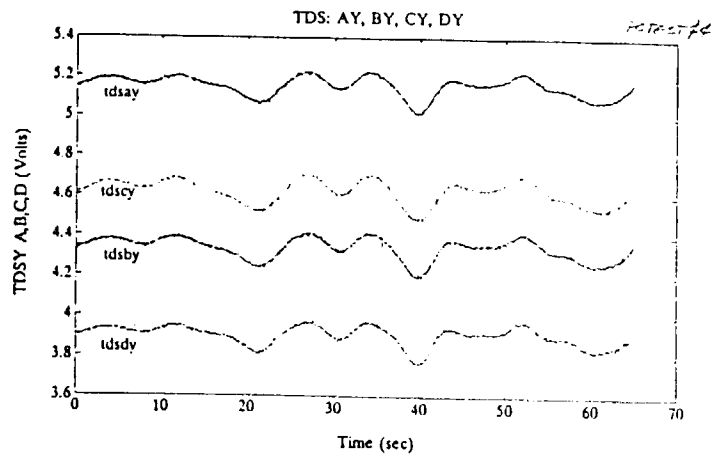
TPB = BLT Differential Pressure = Actual Force

BLT: Preliminary Verification Testing (Volts)

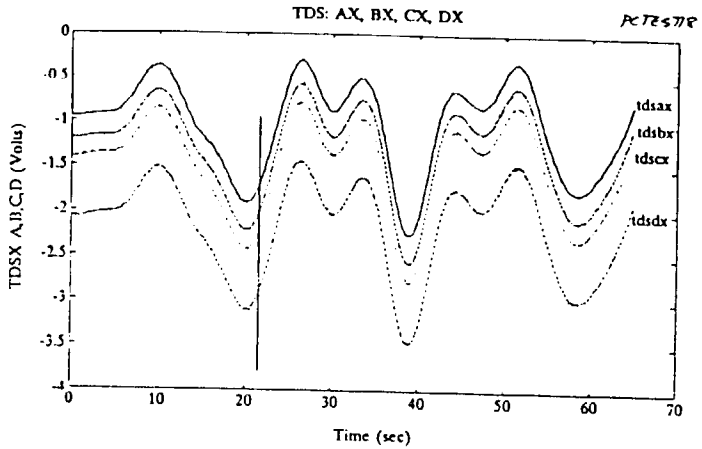
- Test demonstrates: repeatability (2 wks) & TDS "X" response & Linear TDS (= waveforms)

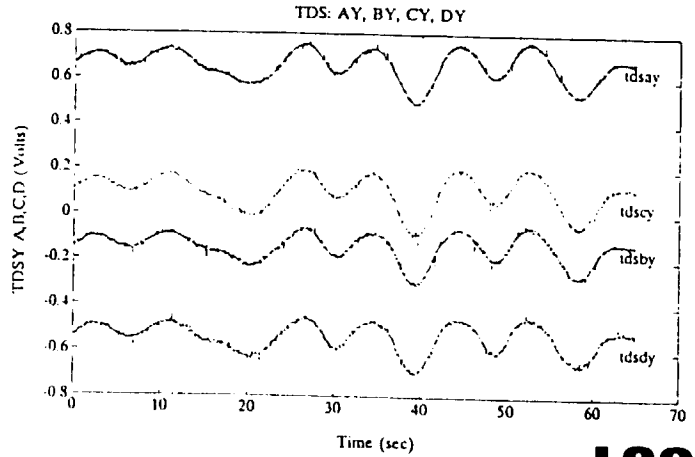
Pctest00: BLT 1 Sine (0.05 Hz)





Pctest18: BLT 1 Sine (0.05 Hz)





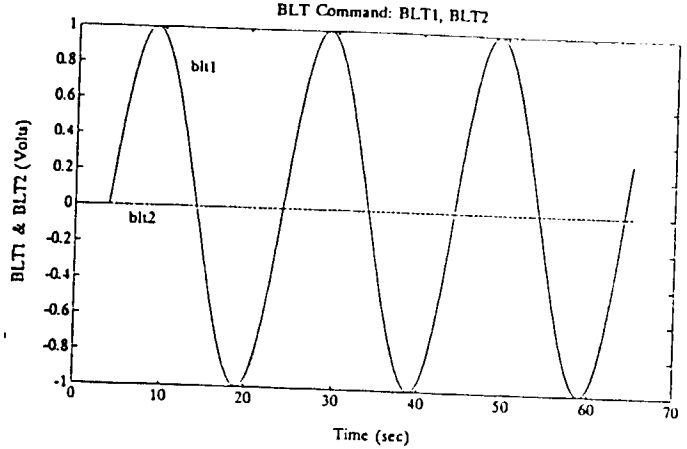
LOGICON

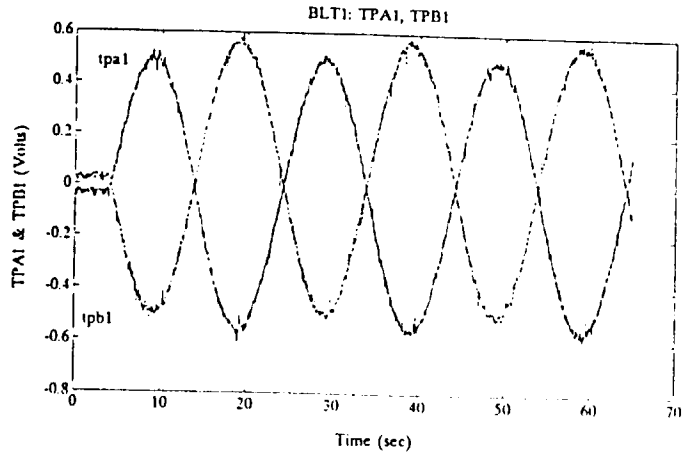
Control Dynamics

BLT: Preliminary Verification Testing (Volts)

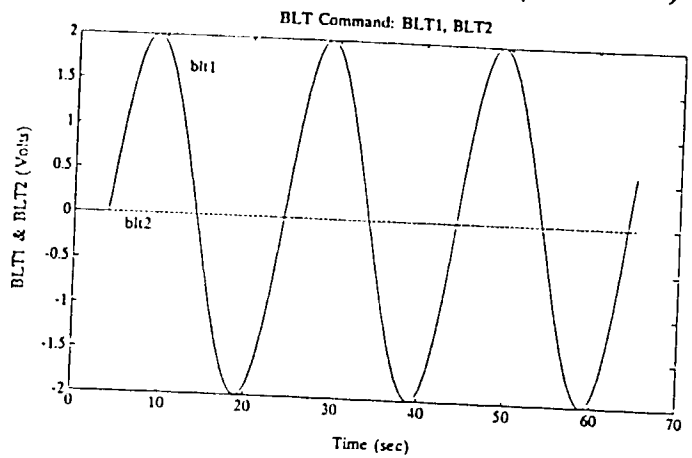
- Test demonstrates: nonlinearity for larger magnitude commands (Command, TPA & TPB)

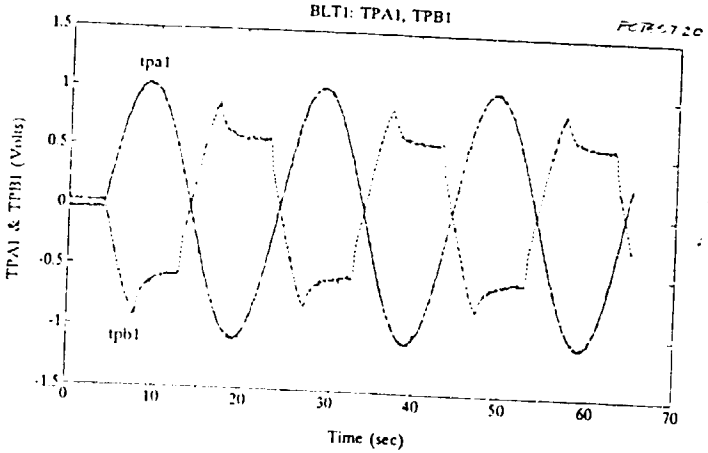
Pctest00: BLT1 1 V Sine (0.05 Hz)





Pctest18: BLT1 2 V Sine (0.05 Hz)

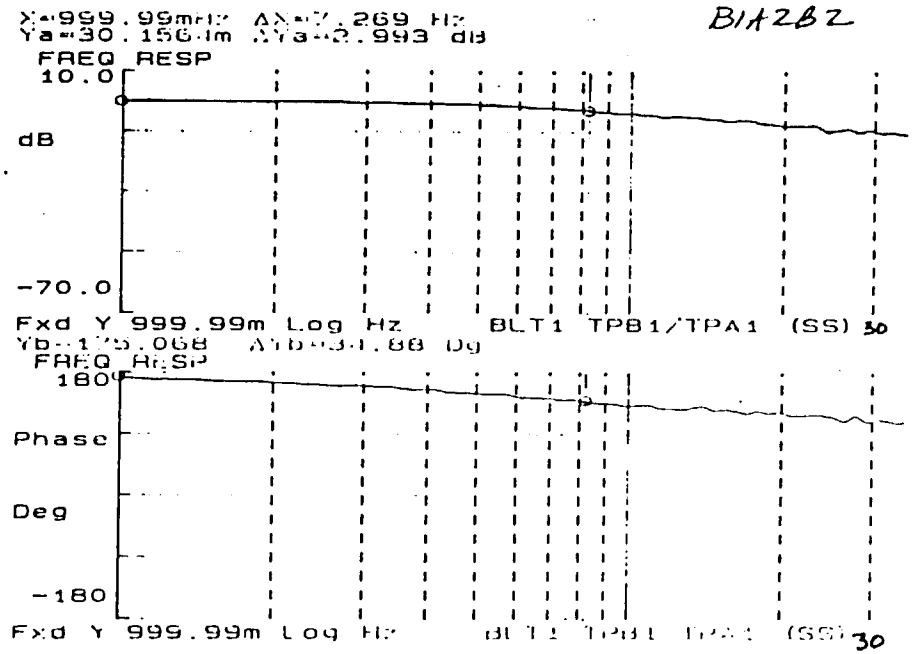


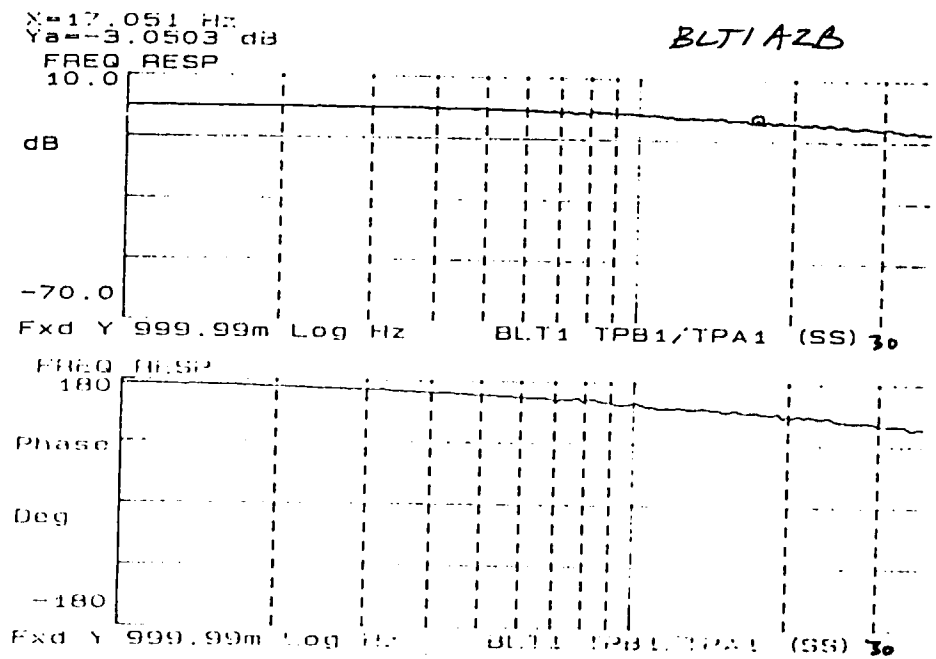


BLT: Characterization Testing (Volts)

- Test: BLT1 Sine Sweep: 1 - 50 Hz (0.5 V pk)
- Examine Transfer Function (TPB/TPA = Actual/Cmd) at different tip pressure
  Expect Actual = Cmd (0 dB, 180 deg out of phase)
- Test shows: 7.5 Hz Bandwidth 17 Hz Bandwidth

B1A2B2: Pressure=133 psi BLT1A2B: Pressure = 162 psi





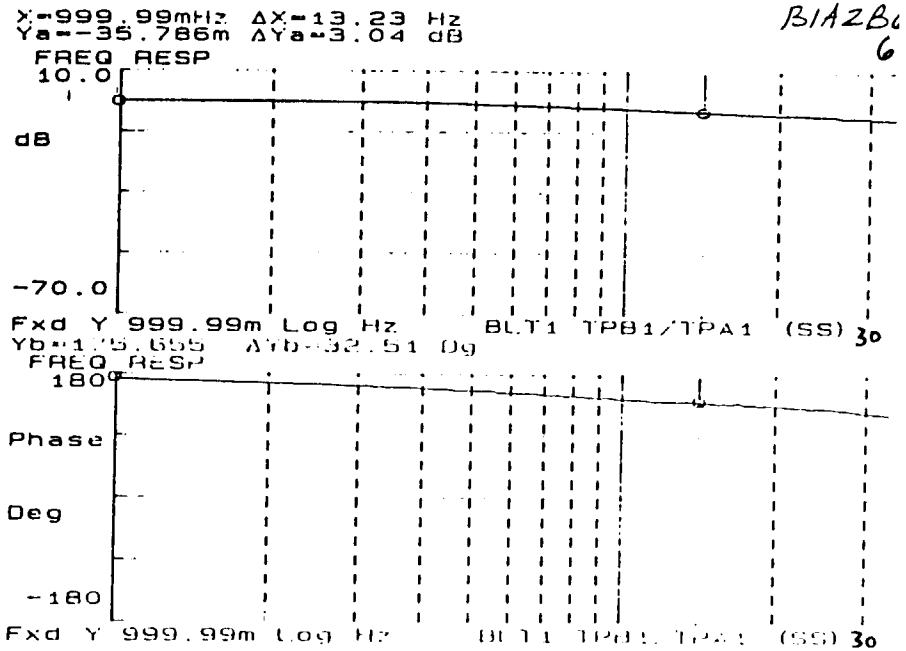
LOGICON

Control Dynamics

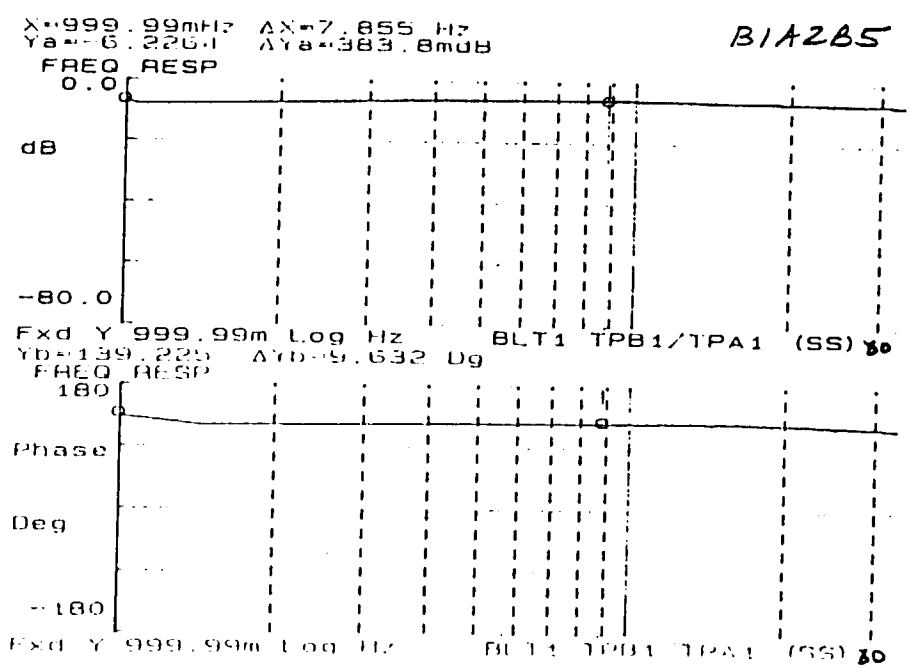
BLT: Characterization Testing (Volts)

- Test: BLT1 Sine Sweep: 1 - 50 Hz (150 psi at tip)
- Examine Transfer Function (TPB/TPA = Actual/Cmd) at different Max command voltages
  Expect Actual = Cmd (0 dB, 180 deg out of phase)
- Test shows: 13 Hz Bandwidth ?? Hz Bandwidth (Flat: -6dB at 1 Hz)

B1A2B6: Cmd Volt = 1 V Pk



B1A2B5: Cmd Volt = 2 V Pk



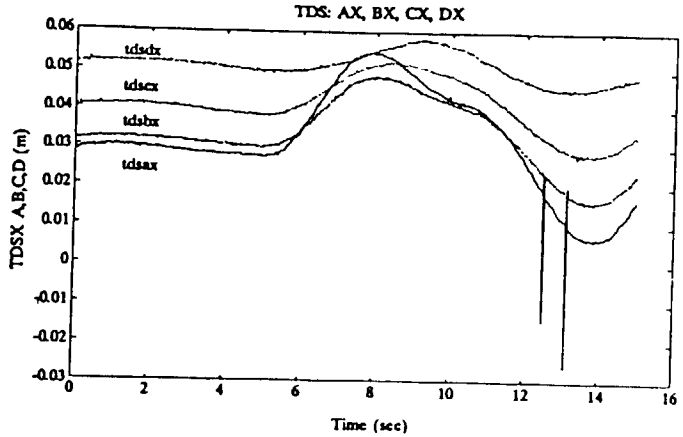
LOGICON

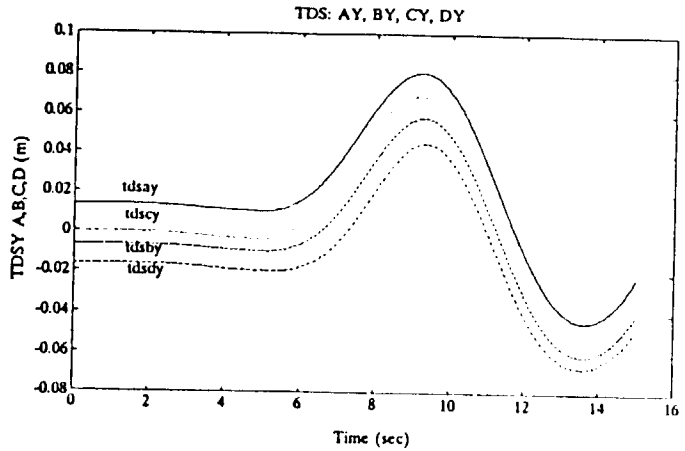
Control Dynamics

BLT: Sign Testing (EUs)

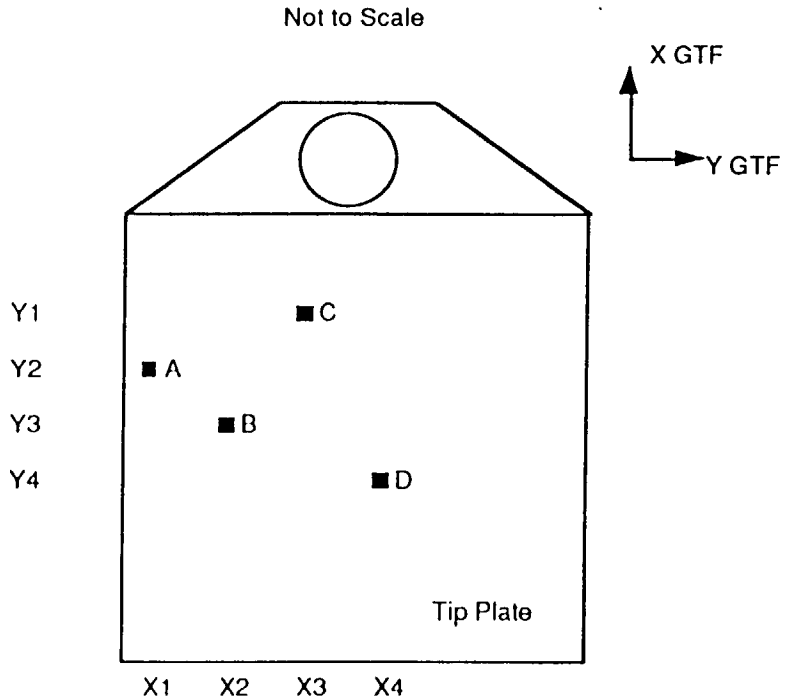
- Test: Positive Thruster Pulse in Y -> Tip Plate Rot'n -> Dissimilar TDS waveforms

Pctest45: TDS X & Y





Tip Displacement Sensor Targets



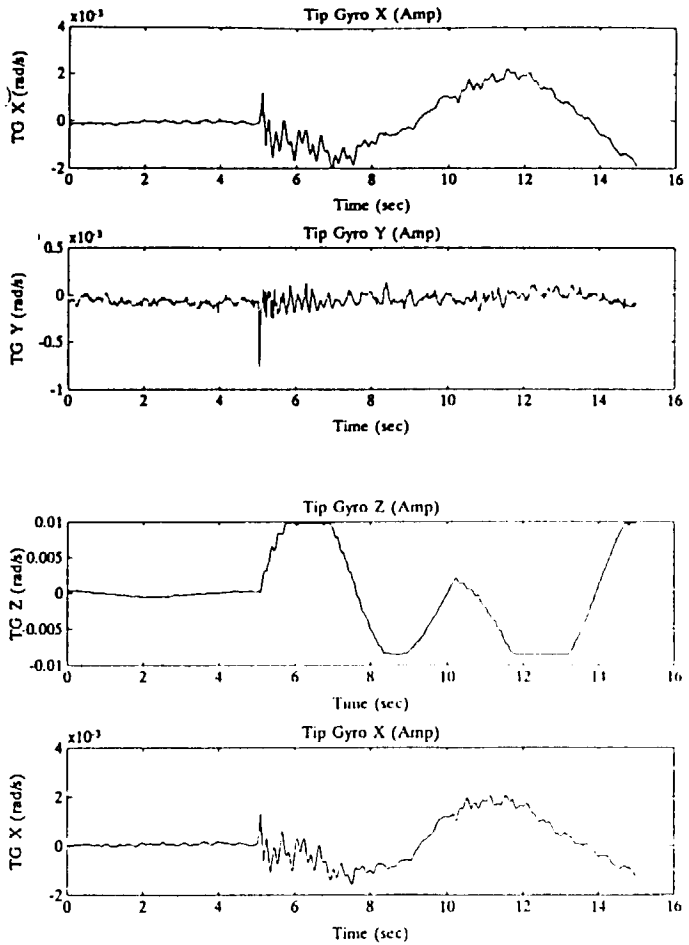
LOGICON

Control Dynamics

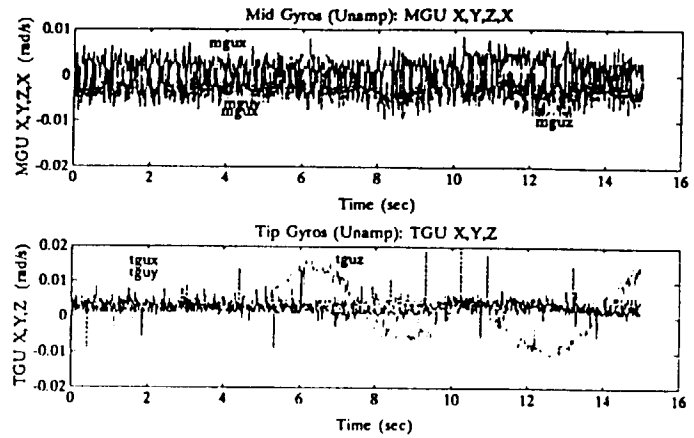
BLT: Sign Testing (EUs)

- Test: Thruster Pulse in +Y -> Tip Plate Rot'n +Z
- Test Shows: Gyro response (+Z), Amp & Unamp Magnitude agree, X & Xredundant agree

Pctest45: Tip Gyros (Amp)



Pctest45: Tip Gyros (Unamp)



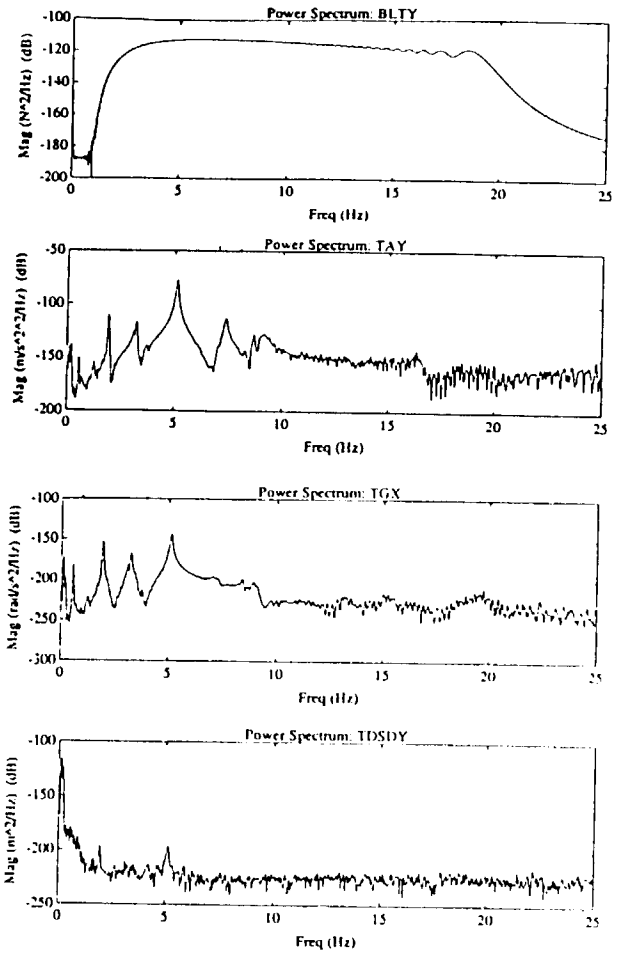
LOGICON

Control Dynamics

BLT: System ID Testing (EUs)

- BLTY Test: 5 Log Sine Sweeps (1 - 20 Hz) in 20 sec, 13 sec zero command

Pctest63: Power Spectrums



Input BLTY (Sine Sweep)

Tip Accel Y
8 modes: 1T, 2T, 2BY, 3 BXY, 5BY

Tip Gyro X
Sees mostly same modes as TAY

TDSDY
Sees only pendulum mode Y 0.11 Hz

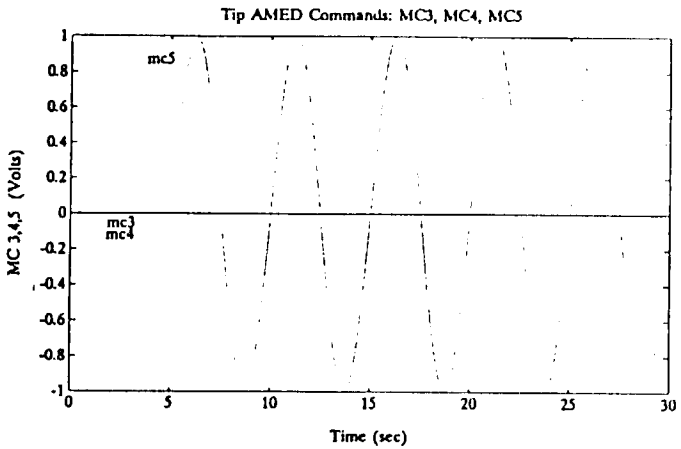
Thruster System: Future Recommendations

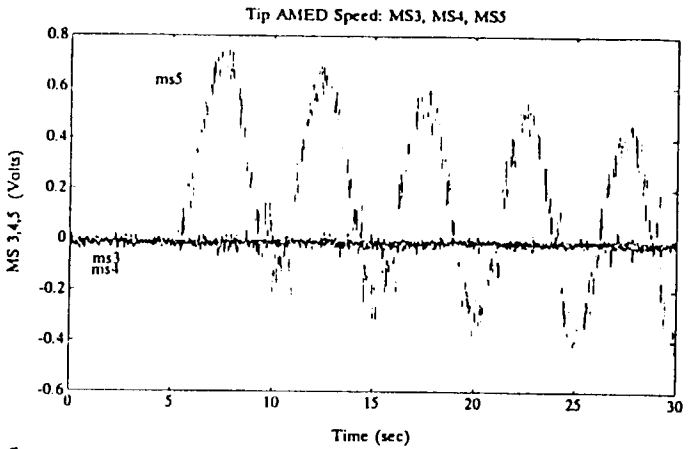
Recommended Upgrades	Benefits
Investigate possibility of adding pressure regulator at tip	Allow higher bandwidth & performance
Investigate higher pressure air supply hose to tip	Allow higher bandwidth
Investigate possibility of individual thruster supply hoses	Reduce dependency of thrusters on same hose
Incorporate permanent TPB signal to SMS to warn when Command is not equal to actual thrust	Warning when actual thrust is not following command

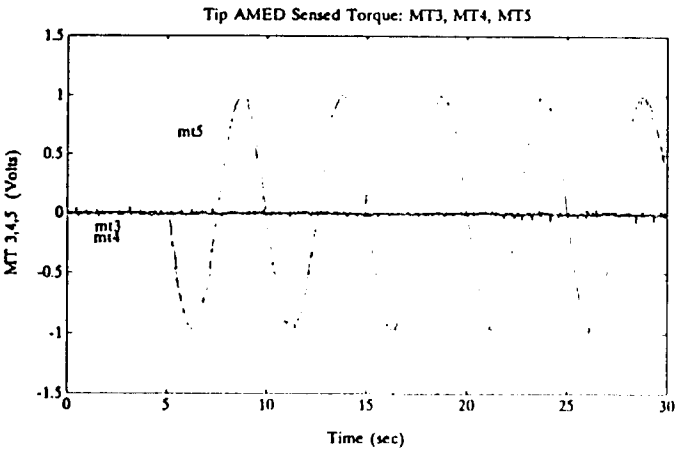
BLT Bidirectional Linear Thruster
SMS Safety Monitor System
TPB Test Point B (on thruster)

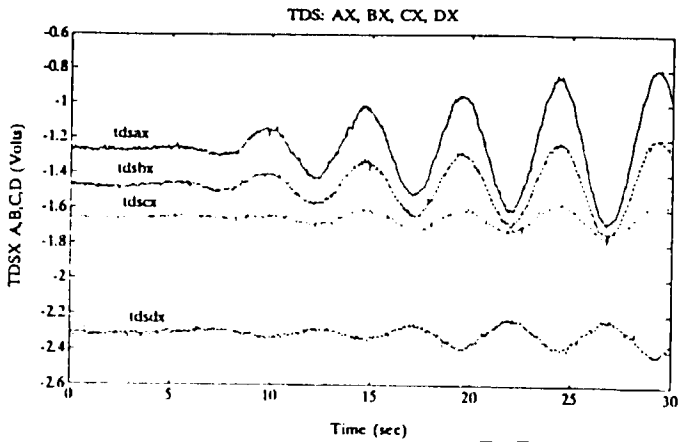
AMED: Preliminary Testing (Volts)

- Test: AMED 5 (Tip Z) Sine wave 0.05 Hz Torque command
- Pctest39 Shows: Torque follows Cmd, Speed is noisy & drifts, TDS shows Rot'n about Z







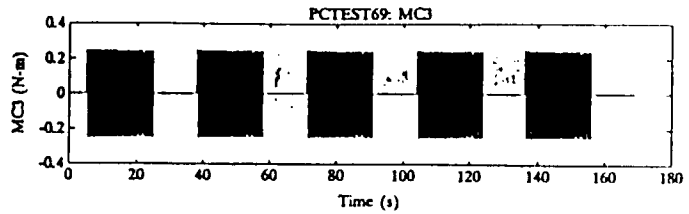


LOGICON

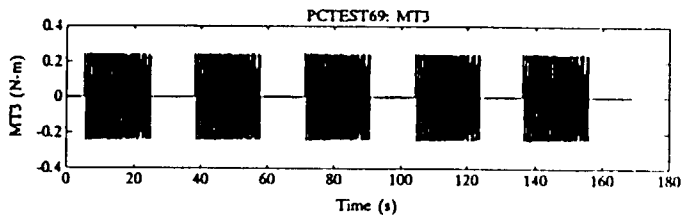
Control Dynamics

AMED: Transfer Function (EUs)

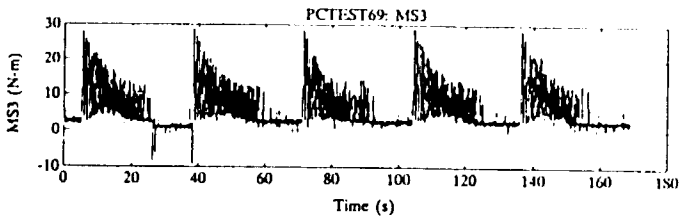
- Test: AMED 3 (Tip X) Torque: 5 Log Sweeps (1-20 Hz) in 20 sec, 13 sec decay time
- Pctest69 Shows: Torque follows Cmd, Avgs are repeatable, MS occasional spikes near 0



Motor Command



Motor Torque (Sensed)

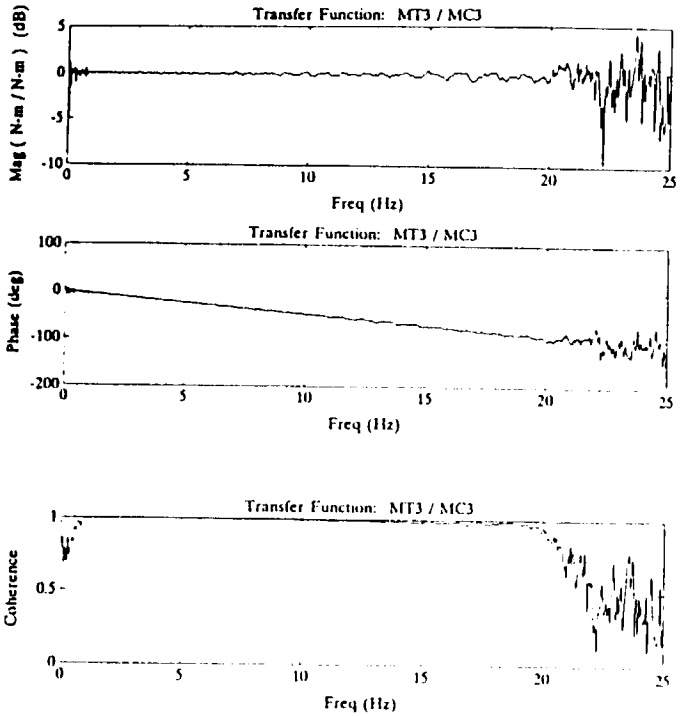


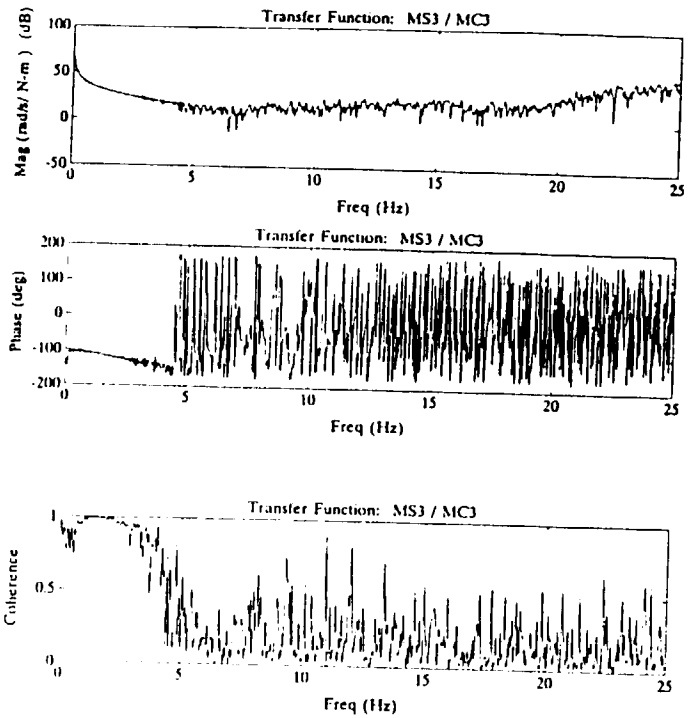
Motor Speed

AMED: Transfer Function (EUs)

- Test: AMED 3 (Tip X) Torque: 5 Log Sweeps (1-20 Hz) in 20 sec, 13 sec decay time
- Pctest69 Results: Transfer Fcns: MT3/MC3 Torque follows Cmd thru test range

MS3/MC3 Speed is a low BW meas't & Noisy
Speed phase -90 deg & Mag -20 dB/dec
Coherence only good to near 3 Hz





LOGICON

Control Dynamics

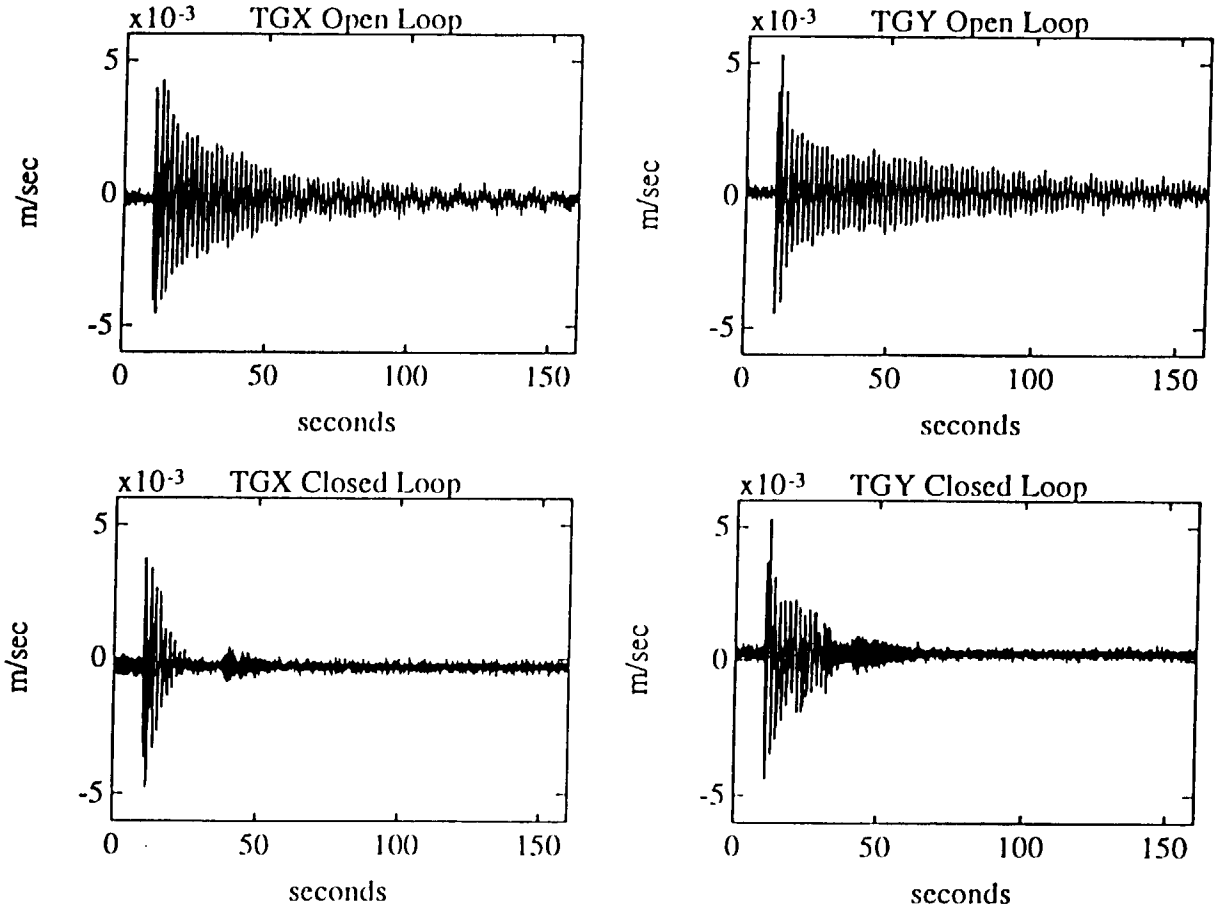
AMED System: Future Recommendations

Recommended Upgrades	Benefits
Redesign Reaction Wheel/shaft mount	Reaction wheels will be safe Extend allowable Torque & Speed range
Redesign RW speed Measurement	Increase bandwidth of speed mea't Reduce noise & spikes near zero
Recalibrate gyros with new preamp gains	More accurate gyro scale factors
Characterize gyros in AMED chassis	Account for misalignment between gyros and chassis
Fabricate working motor/RW demo for visitors	PR plus Backup AMED system

AMED Angular Momentum Exchange Device
RW Reaction Wheel

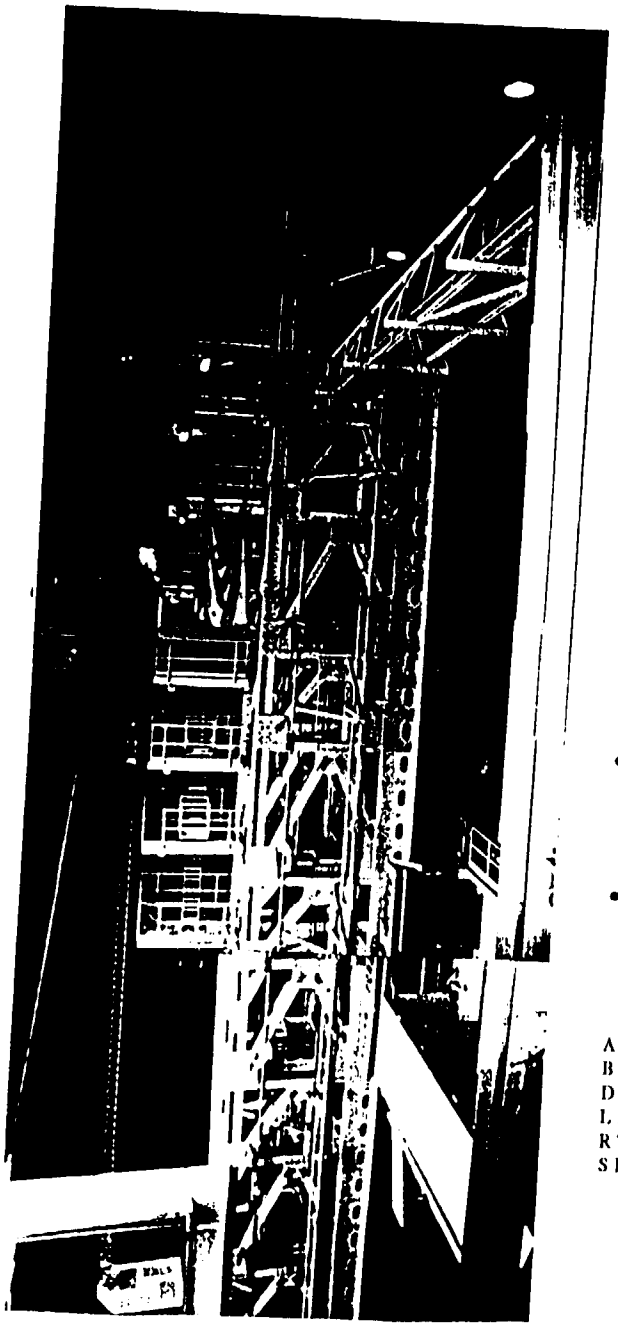
Closed Loop Testing

- First Closed Loop Test (Aug 92): Harris Guest Investigator
- Pctest113/121: Disturbance X & Y Pulses Response: TGX & TGY



LOGICON

Control Dynamics



CSI GTF Status

- Disturbance System Integrated
  (Tripod, Air Pads, Shakers, Shaker Elec, LMS/AS, Sensors, Power, Mux's)
- MPESS, Boom, Tip Plate, Sim Detector Integrated
- AMEDs, BLTs, 5th RW, Accels, BMT/TDS Integrated
  (Only preliminary testing done on BMT)
- Mux/Demux, Power, Cables, Rack Complete & Integrated
- RTCC, SMS, & BMT DAS Operational
- MPESS Access Platform Operational (Manual)
  Facility Enclosure System completed
- Integration completed & Functionality and System ID Testing Performed

AMEDs	Angular Momentum Exchange Devices
BMT	Boom Motion Tracker
DAS	Data Acquisition System
LMS/AS	Linear Motion System/Alignment System
RTCC	Real Time Control Computer
SMS	Safety Monitor System

BLTs	Bidirectional Linear Thrusters
CSI	Control-Structures Interaction
GTF	Ground Test Facility
MPESS	Mission Peculiar Experiment Support Structure
RW	Reaction Wheel
TDS	Tip Displacement Sensor

LOGICON

Control Dynamics

Conclusions

- **ACES Laboratory** operational: Demos & GIs

- **CSI/CASES GTF** operational

  Integrated facility: DS, AMEDs, BLTs, RTCC, SMS, M/D, BMT/TDS, Power MPESS, Boom, Tip Plate, VMS

  Performed Modal Testing (NASA)

  Developed Preliminary Model & Simulation

  Performed Validation, Testing & Characterization

  Performed Open and Closed Loop Testing

- **LSS Team: Significant Progress**

THE END

Appendix A. Control Room Documentation

ACES Documents in File Cabinet

SUBJECT:	AUTHOR:
ACES/SSC Lab General	
General Info: Facility Blueprints, Scale Factors, Blueprints	
Operator's Manual	(LCD)
ACES Final Report (6/88) & ACES Interim Presentation (4/87)	(LCD)
Guest Investigator Program Phase I (Apr 91)	(LaRC)
Guest Investigator Overview	(BDM)
ACES System Documentation	(LCD)
ACES General: Papers & Technical Memos (TMs)	
Report: Definition of Ground Test for LSS Control Verification (11/84)	(LCD)
Definition of Ground Test for LSS Control Verification (11/84)	TM-86495 (MSFC/LCD)
MSFC Ground Exp't for LSS Control Verification (12/84)	NASA TM-86496 (MSFC/LCD)
Ground Test Experiment for LSS (11/86)	NASA TM-86489 (LCD/MSFC)
NASA-VCOSS Dynamic Test Facility (2/85)	NASA TM-86491 (MSFC/LCD)
Active Control of LSS: An Intro & Overview (2/85)	NASA TM-86491 (LCD/MSFC)
Ground Facility for LSS Dynamics & Control Verification	NASA TM-86558 (MSFC)
LSS Testing (2/87)	AAS 87-036 (MSFC/LCD)
LSS Testing (6/87)	NASA TM-100306 (MSFC/LCD)
Schemes for Improving ... Freq-Domain Models of LSS	AAS-87-453 (LCD/Ohio U)
ACES Program: Lessons Learned (6/87)	ACC Paper (LCD/MSFC)
An Application of High Authority/Low Authority & Positivity (6/88)	(LCD/MSFC)
Presentation: Control Design for ACES (5/92)	(Ohio U)
Sensors	
Optical Sensor (TRW):	
Test Plan (VCOSS) (1/86) & Mechanical Blueprints (10/86)	(TRW)
Report (Sections): Optical Pos'n Sensor, Linear Actuators, Electronics, Mirrors	(TRW)
Final Report: 3/84-3/86 (LMEDs & Optical System)	(TRW)
Optical Sensor Testing Report	(LCD)
IMC Laser/Mirror: Mirror Drawings, 4-quadrant detector info	(MSFC)
IMC analog servo electronics & schematics	(MSFC)
Manuals: Laser Power Supply, Pointing Gimbal Power Supply	
Laser Safety Guide & Guide for Selection of Laser Eye Protection	(LIA)
ATM Gyros: Overview, ATM Gyro Processor System Description Report	(MSFC/LCD)

Base Gyro Transfer Functions (11/90) (MSFC)
KARS: Overview, Tip Gyro transformations (LCD/Kearfott)
US Army RPV ARA Interface Definition (4/79) (Kearfott)
Kearfott Attitude Reference System Manual (2/80) (Lockheed)
LaMOD User's Manual (7/91) (LCD)
Base Accelerometers Overview (Digital) (MSFC/LCD)
Tip Accelerometer Info (PCB)
Tip Mounting Plate Drawing

Actuators
AGS: Overview, Electronics Schematics (1/83) (MSFC)
Thrusters Report (7/87) (Aerojet)
LMEDs:
Electronics Schematics, Mechanical Blueprints, Test Report, Motor Specs (TRW)
LMED Accelerometer Calibration Sheet (Sunstrand)
(TRW) Memo (11/85) & Test Plan (1/86) (TRW)
Characterization & Hardware Modification of LMEDs (2/87) (LCD)
Characterization & Hardware Modification of LMEDs (2/87) NASA TM-86594 (LCD/MSFC)
Distributed Control using LMEDs (10/87) NASA TM-100308 (MSFC/LCD)

Computer
AP500 Information
ACES Software Description: HP Basic, COSMEC, AP descriptions & listings, etc... (LCD)
Dell Computer (DAS Panel - Analog Devices)
Anti-Aliasing Filter Report (7/90) (LCD)
COSMEC: (3/82)
Electronics Schematics, Software Listing (MSFC)
Hardware/Software: Original System (Software Listing) (MSFC)
Hardware Math for 6502: Original System (7/85) NASA TM-86517 (MSFC)
Wavetek Software

Test Article
Antenna/Arms Blueprints (2/85) (MSFC)
BET X-Y Table Blueprints (9/83) (MSFC)
BET Analysis Informal Report (6/84) (LCD)
Roll Tip Motor Design

Lab Information

Power Supply Manuals: Lambda, Topward, Sorenson
Video Monitor System Manuals: Panasonic TV, VCR, Quad System, Camera
Lab Supply Manuals (DMM, Scope, Solder Station, etc....)

CASES Documents in File Cabinet

System Information

General Info	(LCD)
CASES GTF AAS-92-024	(MSFC/LCD)
Scale Factors	(LCD)
CASES System Test Plan	(LCD)
GTF Scale drawings	(LCD)
CSI/CASES System Documentation	(LCD)
CSI/CASES Operator's Manual	(LCD)
VMS User's Manual	(LCD)

Facility Information

GTF Platform Design Blueprints (5/88)	(Williams-Russel &Johnson)
CASES Lift Crane Document (3/90)	(Valley Steel/MSFC)
Air Panel Blueprints	(TBE/MSFC)
MPESS Access platform materials & Blueprints (10/91)	(Sverdrup/MSFC)

Test Articles

SAFE/CASES Boom:

SAFE Experiment Blueprints	(Lockheed)
SAFE/Dynamic Augmentation Experiment (87) NASA TP-2690	(MSFC)
SAFE Final Report (4/86)	(Lockheed)
Re-verification Test Report for the SAFE Mast Assembly (3/83)	(Able)
CASES Boom Report: Final ... SAFE Mast Mod for CASES Pgm (2/90)	(Able)
Tip Plate: Experimental & Analytical Studies (6/90)	(U of Alabama)
CASES Tip Plate Assy: Prelim Designs & Fabrication Procedures (12/89)	(U of Alabama)
MPESS Blueprints	(Campbell)
AMED Blueprints	(MSFC)
Tip Plate/PMS Blueprints	(MSFC)

Actuators

AMEDs:

Inland Motor User's Manual, Operating Instructions for Motor Controller	(Inland)
AMED Motor Speed Board & AMED Testing Report	(LCD)
AMED Test Results (integrated with facility)	(LCD)
BLT Development & Test Report (2/90)	(Boeing)

BLT Test Results (integrated with facility) (LCD)

Disturbance System
- Disturbance System for CASES CDR Report (7/88) (LCD)
- Rotary Table Blueprints (Troyke)
- Linear Motion System Guide (Thomson)
- Model 6 Shaker Manual (Unholz-Dickie)
- Tripod Finite Element Model Report (12/89) (LCD)
- Ring Finite Element Model Report (10/89) (LCD)
- Flowmeter Manual & Calibration Sheets (Sponsler)
- Pressure Transducer & String Pot Specification Sheets (Celecso)
- Force Transducer Manual (PCB)
- Optic Probe User's Manual (LCD)
- Air Gap Capacitance Meter Report (& Testing) (1/92) (LCD)
- Air Bearing Manual & Testing Report (12/89) (LCD)
- Ring Epoxy Pour Plan (2/89) (LCD)

Sensors
- Conex Gyros:
  - Kearfott Gyro Test Results (6/87) (Kearfott)
  - MSFC Gyro Test Results (9/91) (MSFC)
  - Gyro Preamp Report (1/92) (LCD)
  - CONEX Gyro Manual + correspondence (Kearfott)
- BMT/TDS:
- PCB Accelerometers: Manual & Calibration sheets & Power Unit Manual (PCB)
  - General Guide to ICP Instrumentation (PCB)
- TRW Optical Sensor (Also see ACES Sensors):
  - VCOSS Technical Memo & VCOSS-II MSFC Test Plan (1/86) (TRW)
  - TRW Optical System Testing (1/92) (LCD)

Signal Processing/Computer
- Signal Processing Document (LCD)
- Differential/Single Ended Converter/Amplifier Report (1/92 (LCD)
- Anti-Aliasing Filter Report (1/92) (LCD)
- Mux/Demux Report (5/92) (LCD)
- Debug Electronics Report (LCD)
- Auto-Cutoff/Sync Generator Report (10/92) (LCD/MSFC)
- Safety Monitor System Report & Software (1/92) (LCD)
- Control Computer Report & Software (LCD)
- RTCC User's Manual (Part of CSI/CASES operator's manual) (LCD)
- IOS Overview Presentation Viewgraphs (AP Labs)

CASES Sensors

BMT/TDS:

- Paper, Final Design Review Viewgraphs, Proposal (Ball)
- BMT overlap analysis (LCD)
- Structural Control Sensors for CASES AAS-90-044 (Ball/MSFC)
- Operation & Maintenance Manual (BMT & TDS) (Ball)
- Technical Documentation for TDS & BMT Report (Ball)
- Blueprints & Electronic Schematics (Ball)
- BMT FIFO test software (LCD)
- BMT FIFO Report (HW/SW & Schematics) (LCD)

CASES Testing/Model/Simulation

- CASES Ring Modal Survey Test Report (8/89) (MSFC)
- Ring Finite Element Model Report (10/89) (LCD)
- Tripod Finite Element Model Report (12/89) (LCD)
- MPESS Modal Test Report (5/90) (MSFC)
- Tip Plate Modal Test Data (11/91) (MSFC)
- CASES Expt Modal Test Report (1/92) (MSFC)
- CSI/CASES Finite Element Model Report (LCD)
- CSI/CASES Simulation Report (LCD)
- System Verification Test Results (LCD)
- System Characterization Test Results (LCD)

ACES Model/Simulation & Modal Testing

- Modal Tests of the LSS Ground Verif Test Facility (10/84) (MSFC)
- Modal Tests of the VCOSS-II Test Configuration (10/85) (MSFC)
- Modal Tests of ACES (9/86) (MSFC)
- Modal Survey Test Report for ACES (6/90) (MSFC)
- ACES Tip Structure Modeshapes (5/90) (MSFC)
- Modal Survey Testing of LSS Antenna, CWs & Mirror (5/90) (MSFC)
- ACES Simulation code (LCD)
- ACES Simulation Informal Report (8/84) (LCD)
- Evaluationa of Cruciform Model (6/86) (LCD)
- Emulating a Flexible Space Structure: Modeling (2/88) (NASA TM-100320) (LCD/MSFC)
- ACES Simulation User's Manual (LCD)
- ACES Finite Element Model Report (4/87) (LCD)

Guest Investigator

- CSI Phase I GI Program: 2nd Year Mid-Year Review (7/90)
- CSI Phase I GI Review: Year End Review (1/90)
- CSI Phase I GI Program: Final Review (4/91)

Bldg 4619 Blueprints

List of papers & publications

Assorted Papers

Extra Copies
- BLT Report (Boeing) 2/90
- ACES Final Report (LCD) 6/88
- ACES Modal Test Report (MSFC) 86
- ACES Modal Test Report (MSFC) 6/90
- Antenna/Counterweight/Mirror Modal Test Report (MSFC) 5/90
- CASES Flight Experiment Phase A Study (11/88)
- TDS/BMT Technical Proposal (Ball) 6/90

Contract Status Reviews 91 (LCD)
Contract Status Review 92 (LCD)

CASES Flight Experiment
- Pinhole/Occulter Facility Pre-Mission Def'n Study: Payload Concept Trade Studies (1/86) (TBE)
- CASES Preliminary Definition Study (11/88) (MSFC)
- Structural Control Sensors for CASES (2/90) AAS 90-044 (Ball/MSFC)

Other Deliverables in Control Room
- ACES Model & Simulation (386)
- CSI/CASES Model (Nastran Input Files)
- CSI/CASES Simulation (TREETOPS input files)
- Test Results (Floppy & Cartridge Tape) in Control Room

References in Control Room

Documentation Desk
- X Windows
- IOS Manuals AP Labs
- Sun Manuals
- Sky Warrior Manuals
- Data Translation Manual
- Qualstar Ministreamer

Bookshelves
- Analogic Manuals (AP 500)
- Borland C++
- Borland Turbo C & Turbo Assembler
- Central Point PC Tools
- Crosstalk Disk Optimizer 4.0
- Dell 310 MS DOS Manuals
- Dell MS DOS User's Guide
- Design CAD 3-D
- EXP Scientific Word Processor
- Gateway 2000 User's Guide MS DOS 5.0
- Graftool
- HP 3562A Manual
- HP 5423 Manual
- HP Manuals
- HP Manuals HP 9000 System (HP Basic OS)
- Lahey Fortran
- Logitech Mouse
- Mathematica
- Matlab for Sun Workstation
- MatrixX & System Build
- Metrabyte Data Acquisition & Control
- Microsoft C Compiler Manuals
- Microsoft Excel
- Microsoft Fortran
- Microsoft Windows
- MSC PAL & MOD User's Manuals
- Norton Utilities
- PC NFS Manuals
- Printer Manuals
- Simulab User's Guide
- Solution Systems Brief
- Word Perfect

Boxes on Bookshelves: 386 Related Unix Software & Manuals

Documentation in Computer Storage Cabinet: Sun OS Reference Manuals

Documentation in Wood Desk:

HP Manuals HP 9000 System (Unix OS)

By Gateway 2000 (SMS):

Data Acquisition National Instrument
Quinn Curtis Real-Time Graphics

By ACES Dell:

Matlab Manuals
IBM DOS 3.0

By HP 9000:

HP BASIC Reference Manuals (2)

NASA Report Documentation Page

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16. Abstract

This report describes the Marshall Space Flight Center's Large Space Structures Ground Test Facilities located in building 4619. Major topics include the Active Control Evaluation of Systems (ACES) Laboratory, the Control-Structures Interaction/Controls, Astrophysics, and Structures Experiment In Space (CSI/CASES), Advanced Development Facility and the ACES Guest Investigator Program.

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